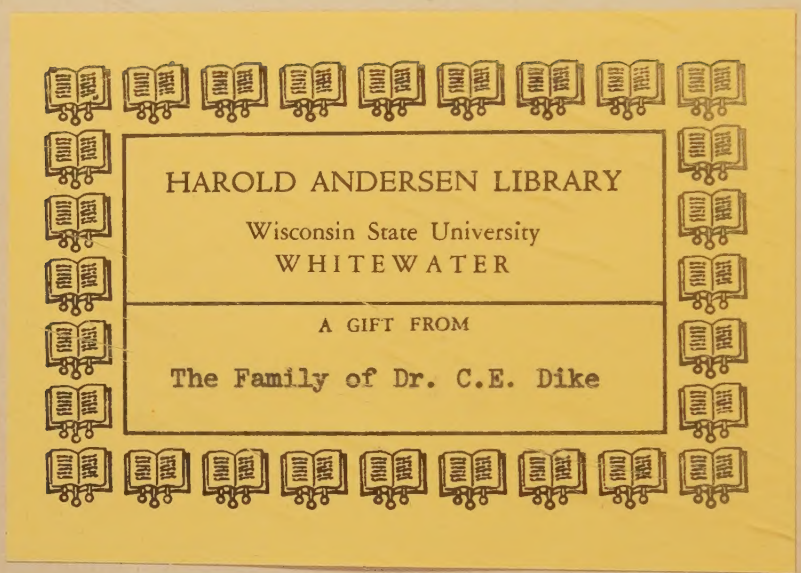

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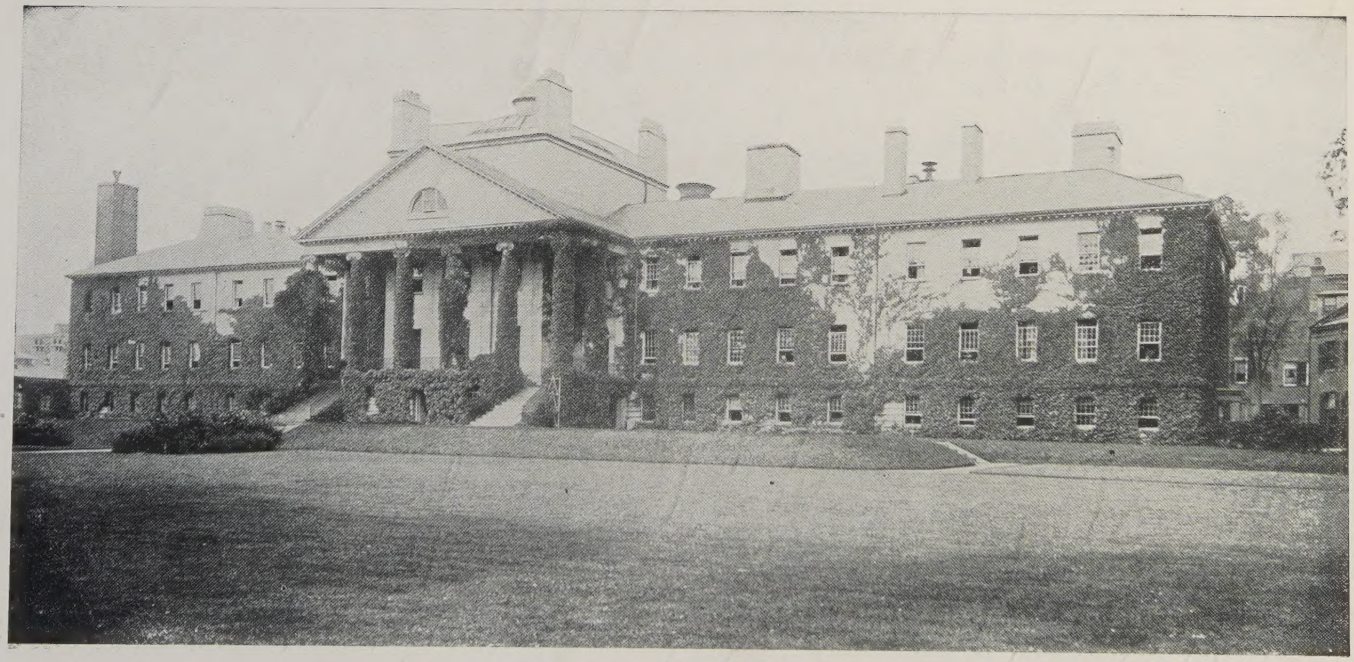

MASSACHUSETTS GENERAL HOSPITAL.

THE TREATMENT

of

FRACTURES

WITH NOTES UPON A FEW COMMON DISLOCATIONS

BY

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TO MY WIFE

ABIGAIL SEELYE SCUDDER

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PREFACE TO THE TENTH EDITION

The opportunity to revise and enlarge certain chapters and to add new material is welcomed. I have attempted in this edition to present the present knowledge of the non-operative and the operative methods of treating fractures.

It is very generally understood that rigid and strictly standardized methods of fracture treatment are undesirable and never can be developed. The variety of conditions attending a fracture will always compel the exercise of careful judgment in the choice of treatment. The reasons underlying the selection of any particular form of treatment are becoming more and more clear.

The present high development of (pathological) general surgery makes possible and eminently proper today a safe operative treatment of this branch of traumatic surgery. Consequently, I have presented the operative treatment as a system by itself apart from its application to any particular fracture.

The method of conducting the operative treatment correctly, provided and only provided that it is distinctly indicated, should be understood and acquired by every surgeon of traumatism.

As the adaptation of treatment to particular fractures is better understood, through the accumulation of well recorded final results, each recent fracture will be treated more ideally and the maximum function will be secured in the shortest possible time commensurate with the nature of the damage done.

Special subjects have been prepared by certain men chosen because of interest, training, and experience. It is fitting that fractures of the jaws should be considered by an oral surgeon.

The chapter on birth fractures is based largely upon the classical monograph of Dr. Truesdell of New York, N. Y., who has had a rare opportunity to study these conditions. The illustrations for this chapter are almost entirely from the original monograph by Truesdell. Sufficient material on massage has been presented from Dr. Mennell's book to orient the surgeon on this important subject. A perusal of Dr. Mennell's monograph will afford complete information. I wish to acknowledge here the assistance received from a multitude of sources, which I have indicated in the text and in the legends of various illustrations. Errors of omission will be gladly corrected if those discovering them will bring them to my attention.

Mrs. Grace W. Myers, Librarian Emeritus of the Treadwell Library at the Massachusetts General Hospital, Boston, has produced a carefully prepared index.

The publishers I thank for again extending every courtesy and facilitating in many ways the completion of this edition.

The incidence of fractures is increasing in the United States. There were in 1924 upward of 155,000 cases of fracture treated in the A grade hospitals of the country.

The results of fracture treatment are too frequently deplorably bad. Crippling from fracture has been understood for years. The economic importance of crippling has been recognized comparatively recently. The surgeon's task is to prevent disability following fracture. The initial early treatment is the easiest and the most important. Most bad results are dependent on inadequate initial treatment.

To insure adequate treatment to a given case of fracture:

A Roentgen-ray record of the injured part should always be had immediately after the injury. The doctor must know what the exact injury is.

The honest intelligent use of a simple accepted form of immediate treatment is imperative.

In every doubtful and difficult case a consulting doctor from a nearby center or from the same town should be employed.

A record of salient facts should be kept, checking the progress of the case.

If it is decided that operative treatment is wise the delegation of this treatment should be to someone competent to do it. "Surgery today is being practised by too many light hearted and incompetent surgeons" (Sir Berkeley Moynihan). Operations on fractures are difficult. Disasters may be terrible from the improper choice of operative procedures, from the inadequate conduct of the operation itself, and from the abbreviated and neglected after-care of the patient. If a physician cannot handle a fracture adequately well from the beginning to the close of treatment, he should be able to recognize this fact, and to so perfect himself in the initial early treatment that he will handicap neither the patient nor the surgeon who may continue the later more difficult care of the case.

CHARLES L. SCUDDER.

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PREFACE TO THE NINTH EDITION

More than six years have passed since the last edition of this book was printed. During this time several principles and procedures tentatively introduced in the treatment of fractures have been applied on a vast scale in the World War. In comparing today's treatment with that of 1915 a veritable revolution is seen to have taken place. A new order has been established. The surgical war experiences have contributed definitely to the advancement of the civil surgery of fractures.

Battle casualties may be more serious than ordinary civil injuries. The principles, however, underlying treatment are the same in military surgery as in civil surgery.

It has come to be more generally recognized that a fracture is not alone a lesion of bone, but may also be associated with injury to the skin, muscles, blood-vessels, nerves, and to bones and joints in the neighborhood of the fracture as well as to the several viscera protected by bony structures.

This fact is the basis of all reconstructive surgery and of attempts made to place the injured individual where he was functionally before the accident. This conception of the fracture of bone as a damage to a complicated human mechanism should predicate the surgeon's efforts to correct the injured part. Treatment is influenced by this conception. The active recognition of the necessity for placing the individual with a fracture where he belongs industrially is one of the important outcomes of the war.

The following indicate progressive improvement in the treatment of fractures:

The Carrel-Dakin treatment of infected wounds, by which potentially septic and septic compound fractures may be controlled, is perhaps the most striking single contribution to modern traumatic surgery.

The recognition of the importance of skilled immediate treatment of recent fractures—*i. e.*, the recognition and proper treatment of shock; the first-aid dressing; the transport; the minimizing of trauma; the emergency traction; the immobilization of the fracture—all this early treatment is simplified.

The universal acceptance of the Thomas splint and the principles of its use—and the acceptance of similar types of splints—is imminent.

The acknowledgment that the indirect and direct traction principle is capable of effectively correcting shortening in fractures of the long bones.

Thousands of gunshot fractures of the long bones obviously unsuited for the fixation of fragments by direct operation have been successfully treated by adequate traction and attest the correctness of the previous statement.

The establishment of the safety and efficiency of direct bony traction, especially in fractures of the long bones of the lower extremity.

The recognition of the necessity for an *x*-ray of every fracture.

The revolt against the general use of metallic sutures and plates. The occasion for the use of metallic materials is more clearly defined.

The adoption of the suspension of fractures of the extremities.

The necessity for the early active movements of joints contiguous to the fracture.

The value of active as distinguished from passive movements of joints.

The adoption of the early active movement of septic joints.

Acknowledgment that the Whitman method of treating fractures of the neck of the femur is based upon sound anatomic and sound pathologic ground and is permanently established as the method of choice.

The segregation of patients with fractures of bone in hospital wards.

The organization in hospitals of fracture services with a permanent personnel, continuous service, and team work.

Carefully planned undergraduate teaching of the subject of fractures of bone.

Systematic courses for graduate instruction in the treatment of fractures.

The gradual recognition of the fact that that surgeon who is most satisfactorily equipped for the care of fractures of bone will be the one who is adequately prepared by a broad general surgical training to care for any damage done the body resulting from fracture, whether it be to brain, spinal cord, thoracic contents, or abdominal and pelvic contents, to nerves and nerve plexuses, to blood-vessels, to muscles, and tendons.

I realize that there is considerable included in the pages of this edition which is a bit old fashioned. In a subsequent edition of printing I propose to eliminate completely everything that savors of historically interesting methods and confine the text to actually used methods of treatment. The new is not generally accepted. Some of the old is still useful, therefore it remains in view.

I wish to acknowledge the many suggestions of associates and friends, and notably Dr. Joseph Blake, Dr. William Darrach, Dr. Adams Leland, Jr., Drs. H. C. Marble, R. H. Miller, T. W. Harmer, John Cummin, Zabdiel Adams, George W. Hawley, V. H. Kazanjian. Acknowledgment has been made in appropriate places in the text and by legends for all illustrations and quotations and suggestions from individuals.

It is my great hope that in time it will be generally recognized that fractures of bone should be treated primarily and at as early a date as is practically possible by surgeons specially interested in and trained in traumatic surgery. Special surgical work should be done only by those well trained in general surgery. Surgeons of traumatism should find ample occupation in every large community.

CHARLES L. SCUDDER.

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THE TREATMENT OF FRACTURES

CHAPTER I

HEAD INJURIES

Conditions following head injury—Shock—Concussion and contusion of brain—Laceration of brain—Compression of brain—Middle meningeal hemorrhage—Intracranial accumulation of fluid—Fracture of the skull—Roentgen ray—Fracture of the vault—Fracture of the base—Symptoms of basal fracture—Various forms of unconsciousness—Diagnosis—Lumbar puncture, precautions in doing—Ophthalmoscopic examination—Signs to be studied after head injury—Treatment of head injuries—Shock—Lumbar puncture—Hypertonic saline solution—Magnesium sulphate—Compound fracture of the skull—Operation demanded—Operation in middle meningeal hemorrhage—Prognosis following injury to the head—Convalescence following head injury—Peets' observations on the reduction of intracranial pressure—Later results of head injury.

It is impossible to consider the treatment of fractures of the skull apart from a more or less systematic review of traumatic lesions of the brain.

The skull is the brain's protection. In cases of fracture of the skull the injury to the brain is of paramount importance. The immediate damage to the brain may be caused by direct pressure of bony fragments, by pressure due to hemorrhage from torn vessels within the skull, by bruising of the brain itself, by cerebral edema, by foreign bodies, and by subdural fluid. Great interest attaches to serious head injuries not only because the brain may be damaged, but because the lesions are often obscured by an intact scalp. A proper determination of the conditions existing after a given head accident necessitates careful observation of symptoms, combined with good judgment in interpreting the signs present. Among all injuries to which the human skeleton is subject, fracture of the skull is distinguished by the relative unimportance of the bony lesion itself and by the preponderating gravity of the associated and complicating lesions in the brain.

It is of great importance to possess a complete understanding of the bony lesions. As these occur one must keep in mind the possible damage to the brain, cranial nerves, cerebral arteries, venous sinuses, and the meninges. There is no rule about the relative proportion of the resulting lesions in the cranium or in its contained structures. Minimal lesions in anyone may be associated with maximal lesions in the others (Wilensky). The increasing number of injuries to the head from automobile accidents makes it incumbent upon the physician to be familiar with the contents of this chapter.

Examination of the Patient.—The following comprehensive method of examining an individual who has received a severe injury to the head should

be carefully followed, bearing in mind always the possible cranial and intracranial lesions, and remembering that a fracture of the skull as such is of secondary importance, that an injury to the intracranial vessels is serious, and that a lesion of the brain itself is most important.

Careful Roentgen-ray examination of the skull should be made in every case of suspected fracture. Negative Roentgen-ray findings are of limited value. There may be an extensive fracture and no brain damage.

If with brain symptoms there is no visible injury to the skull, the head should be shaved to facilitate careful examination. Discretion should be used in deciding for or against shaving the head. If it can be avoided in the case of a woman, of course, it should be. Acute localized pain and tenderness suggest the seat of fracture. Bimanual comparative palpation of the suspected area will discover edema of the scalp if there is an underlying fracture (Munro).

When Was the Accident?—How much time has elapsed between the accident and the first accurate observation?

What Was the Accident?—Was it a fall or a blow? If it was a blow, what was the direction of the blow?

What is the Age of the Patient?—Are the arteries atheromatous and therefore easily ruptured by trivial injury? Is it the skull of a child, which is softer and less brittle than that of an adult?

What Was the Condition of Health Previous to the Accident?—Was it poor—suggestive of kidney disease and uremia? Was the man alcoholic, or is the present condition masked by alcohol taken subsequent to the accident? The urine should be examined—a catheter specimen being obtained if necessary.

The General Condition of the Patient.—If unconsciousness is present, was its onset immediate, or was there a lucid interval after the accident? Has the unconsciousness been continuous, and is it deepening or lessening?

Great importance should be attached to headache as a symptom of milder injuries, often leading, if untreated, to later disabling symptoms.

What Are the Evidences of Shock Present?—What is the condition of the pulse, of the respiration, of the skin? What is the blood-pressure? What is the temperature taken by rectum? Has vomiting occurred? Have there been involuntary dejections? Has there been involuntary micturition?

The Local Condition.—The wound of the scalp, skull, or brain may be evident. If hemorrhage is present, what is its source? Is it from the nose, the mouth, the ear, or into the orbit, an orbital hematoma? Is there a subconjunctival hemorrhage? When did the hemorrhage occur? What was its amount? Was it continuous or not? Palpation should be made of the skull, the neck, the face, the spine, the jaw, and the temporomaxillary joints to detect tenderness or edema.

Are Any Localizing Signs Present?—What is the condition of the pupils, and of the muscles of the face, the arms, and the legs? What is the condition of the reflexes and of the respiration? Does hemiplegia, either partial or complete, exist? What does an examination of the eye-grounds reveal? Examination of the various cranial nerves is important.

Finally, the whole body should be examined systematically for any other injuries than those to the head and to the nervous system. The thorax, the abdomen, the pelvis, the spine, and all four extremities should be carefully examined. Associated injuries, if discovered, may assist in interpreting the nature of the cerebral injury.

Certain conditions following injuries of the head:

(*a*) Shock.
(*b*) Concussion and contusion of the brain.
(*c*) Laceration of the brain.
(*d*) Compression of the brain.
(*e*) Extradural hemorrhage—middle meningeal hemorrhage.
(*f*) Increase in the cerebrospinal fluid pressure.

(*a*) **Shock.**—Traumatic surgical shock is ordinarily present to some degree in all patients who have received an injury to the head.

The shock may be so severe that the patient does not regain consciousness and death follows. It cannot be determined without an autopsy whether such individuals die because of shock or because of medullary pressure. No extensive intracranial hemorrhage or cerebral edema can occur until the period of shock has been survived unless due to rupture of a sinus or of a large arterial blood-vessel.

In cases of shock less serious than the foregoing severe type the patient may be conscious or unconscious; the skin will be pale, cold, and clammy; the temperature subnormal; the pupils dilated and reacting sluggishly to light; the pulse rapid (120 to 135), thready, weak, irregular; the respiration will be rapid (25 to 50); the blood-pressure will be low (95 to 100).

The severe initial shock is usually over within ten hours. Often there is a definite improvement in four to six hours. In recovery from shock the pulse-rate drops, the strength of the pulse-beat becomes nearly normal. If the rate decreases and gets as low as 60 to 50, this is a sign of intracranial pressure. If this low pulse-rate goes lower, a medullary compression is to be feared. Any operative procedure having a decompressive effect on the central nervous system may so relieve the intracranial pressure that the pulse-rate increases, ceases to decline, and recovery ensues.

In recovery from severe shock the respiration becomes normal before the pulse-rate does; this is an important fact, suggestive in prognosis. In cases of shock the skin reflexes disappear first and come back last, while the deep or tendon reflexes disappear last and return first. These conditions obtain also in concussion and should be suggestive. For the treatment of shock see p. 42.

(*b*) **Concussion and Contusion of the Brain.**—A concussion and a contusion of the brain associated with minute bruising of brain tissue will exist after either mild or serious injuries to the head.

The symptoms of concussion are varied according to the severity of the injury. Following *slight concussion* the individual is stunned by the accident; there is simple vertigo, possibly mental confusion, lasting but a short time. Slight headache may be present. After *severe concussion-con-*

tusion there will follow a momentary loss of consciousness, or there may be unconsciousness of longer duration. Vomiting may occur, projectile in character. Headache will probably be present, slight amnesia may exist. Following a still *more severe concussion* the patient will be profoundly unconscious for several days. The sphincters may be relaxed; hence involuntary micturition and defecation will occur when the bladder and rectum become overdistended. Retention of urine and feces is present immediately after the injury. Incontinence is the evidence of overdistention of the viscus in these cases. The pulse will become feeble and slow along with the general systemic depression. The pupils still react to light. The temperature will be subnormal. It is sometimes impossible clinically to distinguish between concussion and contusion of the brain.

The pathology associated with *concussion* should probably be limited to venous congestion and cerebral edema with a rise in the cerebrospinal fluid pressure, and with no intra- or extracortical hemorrhage.

Contusion will include all of the above pathology plus subarachnoid or pial hemorrhages.

Laceration should include the above conditions plus actual laceration of the cortex which eventually becomes cicatricial tissue.

In the pathology of concussion no blood appears in the cerebrospinal fluid. In the pathology of both contusion and laceration there is blood in the cerebrospinal fluid.

The above differentiation, even granting that the conditions necessarily overlap, has some prognostic value (Donald Munro).

Recovery from the immediate effects of concussion of the brain may leave the patient somewhat disturbed mentally and with a more or less complete memory loss of events which occurred at the time of and just subsequent to the injury causing the concussion. There may also persist headache, dizziness, and perhaps nausea.

These symptoms following concussion may be present for days or weeks, and will be a source of annoyance and the basis undoubtedly of post-traumatic neuroses. If these persisting disagreeable symptoms are associated with an increased intracranial pressure and other therapeutic measures (administration of sulphate of magnesium by mouth or rectum) fail, then a subtemporal decompression is indicated and the resulting relief to the headache is surprising.

(*c*) **Laceration of the Brain.**—If there is serious laceration of the brain the symptoms of concussion may be present to a marked degree, and will be characterized by immediate, pronounced, and long-continued unconsciousness. After recovery from the initial shock of the accident fever will be present, which may rise to 103° or 104° F. Concussion alone is never associated with feverishness. Early fever is a sign of laceration. Mental excitement and irritability and restlessness will mark returning consciousness. If the motor areas of the brain are involved, signs of irritation will appear, namely, muscular twitchings and spasms, according to the motor centers implicated.

(*d*) **Compression of the Brain.**—According to physiological experiments invasion of the intracranial space must effect three things: 1, a driving out of cerebrospinal fluid; 2, a compression of the easily compressible veins, causing a venous stasis; 3, a compression of the arterial vessels, causing an anemia of that part.

Kocher divided the phenomena attending compression into four clinical groups dependent upon the circulatory disturbance reached by the abnormal intracranial pressure.

The *first group* of symptoms correspond to a mild grade of compression, an increase in cerebrospinal fluid pressure. Moderate venous stasis results. The symptoms are moderate, a little headache and drowsiness are about all that is noticed. The retinal veins are said to become dilated. This is, however, rather impossible to recognize at the outset. Palliative treatment is indicated.

The *second group* of symptoms correspond to a greater intracranial pressure and venous stasis. Limited pressure results in a local anemia and focal signs. General pressure of subdural origin may result in earlier medullary anemia. Headache, vertigo, restlessness, excitement, and delirium may exist. The face will be slightly cyanotic. If the venous stasis and increasing pressure affect the medulla, then a slowing of the pulse will be noticed. The retinal veins are dilated with or without edema of the optic disks and the spinal manometer registers increased pressure, from 15 to 22 mm. This second clinical group is the most favorable for operative relief of the increasing intracranial pressure.

The *third group* of symptoms with a still increasing intracranial pressure is due to an anemia of the brain. The high-tension pulse is noticed as the anemia of the medulla stimulates the compensatory vasomotor mechanism. The pulse is slow in rate (40 to 50), the optic disk is choked, facial cyanosis is marked, the respiration becomes stertorous. The Cheyne-Stokes pulse and respiration are present. Operation in this stage is imperatively demanded. The chances of recovery with or without operation are slight.

The *fourth group* of symptoms corresponds to the failure of the arterial compensation, the action of the heart and the lungs becomes irregular, the pupils dilate, the pulse becomes rapid, coma increases, and death occurs. This is the terminal stage of medullary anemia.

Slight hemorrhages do not cause symptoms of compression, nor do slight depressions of the cranial bones. Before symptoms of compression appear the cranial contents must be impinged upon to a very considerable extent. *If the compression is sudden* and limited, there is an irritation of the parts involved, which is manifested by restlessness and delirium and by twitching of certain groups of muscles, the pulse is hard and slow. *If the compression is gradual,* whether it be localized or diffused, the brain accommodates itself for some time to the new conditions; the appearance of the symptoms of local pressure is delayed, although they may be relatively sudden in their onset. Any paresis or even a paralysis may be temporary and not demand operation. If the paresis or paralysis is accompanied by

other evidences of persisting or increasing intracranial pressure then there is an indication for lumbar puncture operation. Following the muscular spasms and twitchings due to the sudden onset of pressure there may appear symptoms of *paresis* and paralysis. Loss of power in the face or arm or leg indicates a lesion about the fissure of Rolando, upon the opposite side. Loss of power, for example, in the right arm and right leg indicates that the brain lesion is about the fissure of Rolando upon the left side of the brain. If there is pressure upon the *third nerve* at the base of the skull, dilatation of the pupil upon the side opposite to the pressure will be noticed. This pupil will not react to light. It must be remembered that there may be transient focal symptoms without definite focal injury. As the pressure of the hemorrhage increases the symptoms will again become more general; convulsive movements of the limbs and body appear, and the drowsiness or stupor increases to profound unconsciousness; the pulse becomes rapid and small; and the respiration frequent, shallow, and sighing, or it passes into stertor and Cheyne-Stokes' breathing, as the condition becomes immediately grave; the temperature rises high. Focal symptoms may exist from pressure by bone or blood-clot, apart from loss of consciousness.

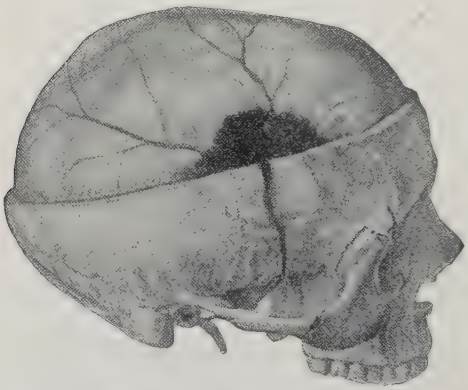


Fig. 1.—Fracture of skull, middle meningeal hemorrhage. Extradural blood-clot (after Helferich).

(*e*) **Extradural Hemorrhage—Middle Meningeal Hemorrhage** (see Figs. 1–4; also Case I, page 55).—A common and important cause of compression of the brain is hemorrhage from the branches of the middle meningeal artery due to laceration of the vessel because of a fracture of the squamous portion of the temporal bone. A most important symptom of traumatic intracranial hemorrhage is the *interval of consciousness* that exists from the time of the injury to the onset of unconsciousness. This period of consciousness may be preceded by the temporary or prolonged unconsciousness of concussion. Unconsciousness in cases of intracranial hemorrhage is due to an increase of the intracranial pressure caused by the presence of free blood. An interval of consciousness exists in these instances in from one-half to two-thirds of all cases. In the cases of hemorrhage which occur without an interval of consciousness (unconsciousness coming on immediately upon the receipt of the injury) it must be that the injury is so severe that the unconsciousness associated with the initial shock or caused by the concussion and laceration of the brain is continuous with the unconsciousness from hemorrhage. The unconsciousness of concussion is continued over into the coma of compression. The duration of the interval of consciousness may vary within very wide limits; it may be a few moments, it may be three months.

In cases of intracranial hemorrhage the first or minor symptoms of compression are found in association with varying degrees of intracranial venous

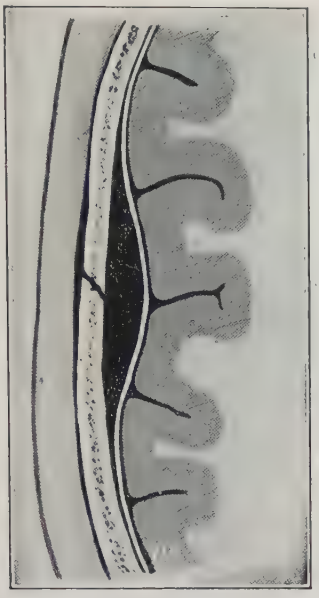


Fig. 2.—Fracture of skull with middle meningeal hemorrhage. Compression of brain by blood alone. Extradural hemorrhage.

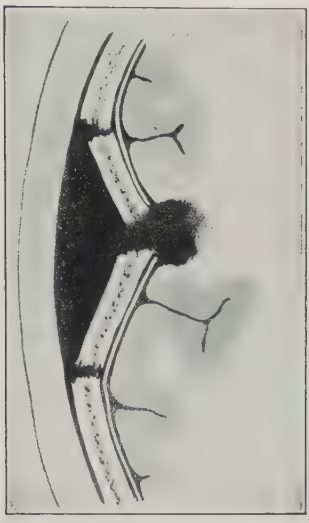


Fig. 3.—Fracture of skull with depressed fragments. Compression of brain by bone and blood.

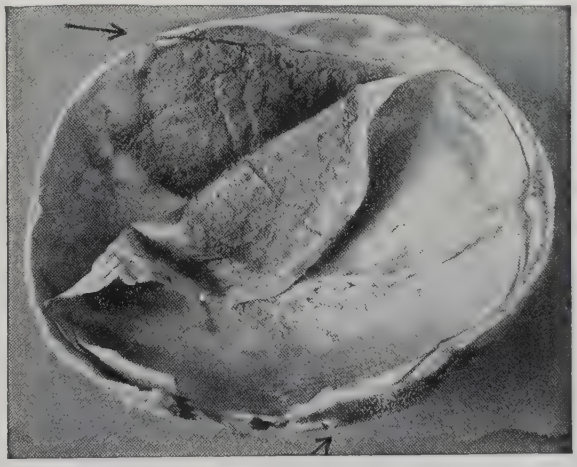


Fig. 4.—Photograph of calvarium with dura reflected, showing extradural clot grooved by the meningeal artery, which had been torn by the linear fissure. From a fatal case of meridional fracture. Arrows indicate line of fracture (Cushing).

stasis, the major symptoms in association with an approaching capillary anemia of the medulla (Cushing, Cannon).

The *sources of intracranial hemorrhage*, whether from the middle men-

ingeal artery or its branches, from the middle cerebral arteries, from the veins of the pia mater, from the sinuses of the brain, or from lacerated brain

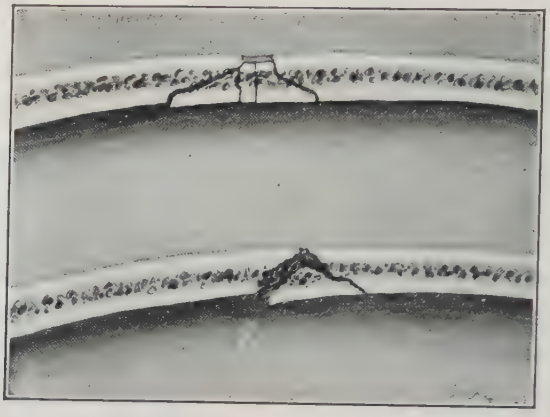


Fig. 5.—Splintering of inner table; cross-sections; diagrammatic: *a*, Usual form of punctate fracture; *b* shows that a linear fracture may be much more extensive internally than externally.

tissue, cannot be easily differentiated short of an operative procedure The most common source of intracranial hemorrhage is the veins of the pia. In several groups of cases carefully analyzed it has been pretty uniformly found that hemorrhage occurs in only about 5 per cent. of the cases from the middle meningeal artery. There is one condition which is not to be overlooked in connection with the question of hemorrhage, namely, the period of semiconsciousness which sometimes follows concussion and laceration, and gives rise to the suspicion of some more serious gross lesion. To illustrate: A young girl received a severe blow upon the head. A true period of unconsciousness followed. There were no external evidences of hemorrhage. Convulsive movements, deviation of the eyes, and disturbance of the pupils were absent. The breathing was regular and of normal character. Notwithstanding the absence of other untoward symptoms, complete consciousness did not return

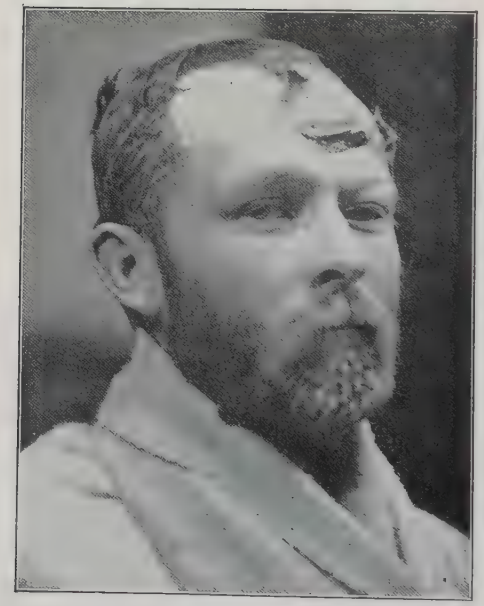


Fig. 6.—Case of compound depressed fracture of the frontal bone. Note extent of depression. Recovery (Harrington).

for a number of weeks. In such a case after a number of days the question naturally presents itself, Have we not to do with a hemorrhage, and should not trephining be considered? The absence of all symptoms excepting the unconsciousness should lead to the suspicion that we have to do with a mental state rather than with a gross lesion. Hysteroid semiconsciousness (Walton) supervening upon a blow is not to be mistaken for the deepening unconsciousness which indicates hemorrhage.

(*f*) **Fluid Accumulations Within the Skull Following Head Injuries.**—A severe blow upon the head, with or without fracture of the skull, may result in a local bruising and in congestion and swelling of the brain tissue, with serous exudation into the subarachnoid space, either with or without edema of the brain substance. If this accumulation of fluid occurs over the motor area, localized symptoms, as if of hemorrhage, will appear. The lesion is usually self-limited, the resulting paralysis disappearing in the course of a few days.

In rapidly increasing edema the interval of consciousness is considerable and the secondary unconsciousness is of slow onset—coming on after a few days—or there may be an irritable semiconsciousness with Kernig and Brudzinski signs—all due to edema of the cerebrum (Stewart).

The careful observation of the onset and sequence of the signs of compression is of the very greatest importance, for it is by a proper interpretation of these localizing symptoms that the surgeon is led to operate, and then is enabled to remove the compressing blood-clot or the depressed fragment of bone and the accumulating fluid.

Fig. 7.—Normal skull. Note relations of facial bones in connection with Fig. 15.

Following a brain injury there is an increase in the fluid content within the skull. The fluid may be extravasated blood, edema of swollen brain tissue, free fluid.

When this fluid is present in any considerable amount a plus intracranial pressure results.

1. Middle meningeal extradural hemorrhage has already been mentioned, see p. 22.

2. The swollen contused edematous cerebral tissue which varies from small petechial hemorrhages to the plum colored, lacerated, and disorganized brain with differing amounts of free bleeding have been mentioned in connection with laceration of the brain.

3. The subdural fluid accumulations (Naffziger) indicate normal fluid in an abnormal location—extra-arachnoid. No normal communications between the subdural and subarachnoid spaces are known.

Presumably tears occur in the arachnoid through which cerebrospinal fluid passes into a space from which little or no absorption occurs (Naffinger).

These subdural collections of fluid represent a definite clinical group.

Along with the customary signs of increased intracranial pressure—slow pulse, high pulse pressure, stupor or unconsciousness, rising blood-pressure, altered respiration, and rhythmic recurring restlessness (Naffziger)—it is not unusual for a hemiparesis to be present. Removal of this subdural fluid accumulation, with or without drainage for forty-eight hours, will relieve general pressure and the hemiparesis will disappear—exactly as after the removal of a large subdural clot of blood.

A true "edema fluid" is fixed in the cerebral tissue, not free as is this subdural fluid. Spinal puncture will temporarily relieve intracranial pressure, for it drains the subarachnoid space, not the subdural space. In mild cases spinal puncture may be all that is necessary.

If the relief is but temporary, a subtemporal opening with drainage will yield more satisfactory permanent results. Naffziger has met such cases soon after injury and as late as seven days after the original accident. In these cases a subdural collection of several ounces of clear fluid was evacuated with complete relief.

FRACTURE OF THE SKULL

Many fractures of the skull are undiscovered and are not suspected. The sequelæ of fracture of the skull make it mandatory that if a fracture exists it should be recognized.

Every skull that either directly or indirectly is injured, and whether symptoms of intracranial pressure are present or not, should be regarded as having been fractured until it has been proved by x-ray examination that a fracture is not present.

Whether the wound of the bone is compound or simple, open or closed, is of great importance, because of the very great likelihood of sepsis. Fractures involving sinuses and the pharynx may prove to be sources of sepsis. A knowledge of the nature of the fracture will help in determining the injury to the brain. If there is a perforating fracture, or if the fragments are comminuted or depressed, then it is highly probable that a tremendous or sharply localized force has been exerted upon the bone, and that, in consequence, the injury to the underlying brain is serious. It is a generally accepted fact that the skull may be simply contused and the great lateral sinus ruptured, with resulting fatal hemorrhage. It is likewise true that the bone may present but a fissure, but if that fissure crosses the middle

meningeal artery or any of its branches, they may be torn across (see Figs. 1, 2, and 4), and the consequent hemorrhage and associated intracranial pressure will prove disastrous unless checked by surgical interference. On the other hand, the bone in the frontal region may be greatly damaged, literally crushed, and yet no grave symptoms arise (see Fig. 6). The *extent* of the bone lesion is of the greatest importance, as it is a measure of the severity of the trauma to the head and hence to the brain.

Roentgen Ray.—The roentgenological examination of the skull in all cranial injuries should be an established routine. The *x*-ray is a guide as to the location and the extent of the bone lesion. Negative *x*-ray plates are unimportant. The positive ray will assist in the prognosis of the case. When possible, stereoscopic films should always be made of the skull. Five roentgenograms should be made of every suspected skull injury. The very

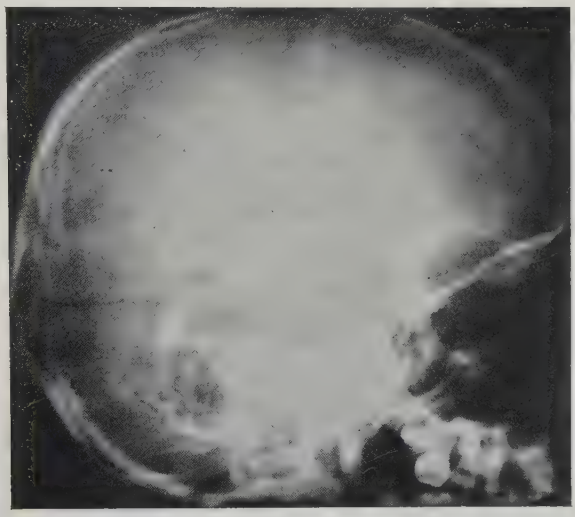


Fig. 8.—Roentgenogram of skull fracture. Note linear fracture in occipital region (Rourke-George).

fact that the cerebral injury is the most important effect of trauma to the head emphasizes the necessity for the most ideal examination and treatment of the associated skull fracture.

It is important to determine as accurately as possible the situation and extent of cranial fractures and the lines of radiating fracture. *It is far more important* to know the damage done the brain and to know whether there is an increased intracranial pressure (local or general) and whether that increased pressure is progressing or not.

Fracture of the Vault of the Skull (see Fig. 9).—Fractures of the vault of the skull *without* involvement of the base are much more unusual than is generally supposed. More than two-thirds of all fractures of the vault are associated with fracture of the base of the skull (see Figs. 9–12). Evidences of fracture of the vault are determined by sight and touch. A wound in the scalp may disclose the fractured bone. Whether this is a mere fissure

or a single or a comminuted fracture, whether depressed or not below the general surface of the normal skull, can be determined only by careful in-

Fig. 9.—Depressed fracture of frontal bone from outside, showing depression of fragments (Warren Museum Specimen 7951).

spection. A fissure of the bone may be difficult of recognition. It must be remembered in this connection that blood cannot be wiped from a fissure,

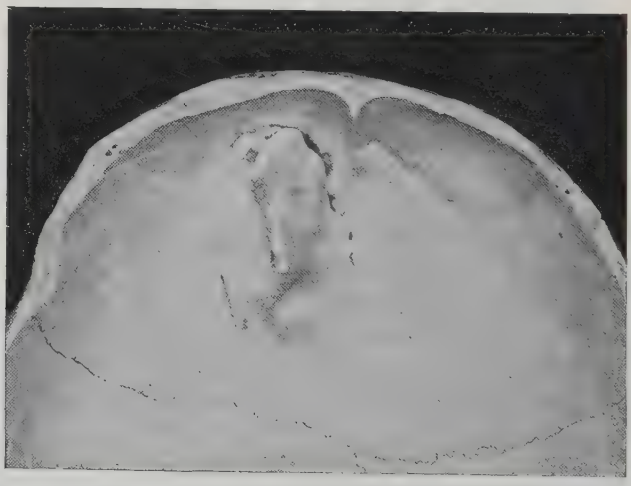


Fig. 10.—Same as Fig. 9; inner surface from within; shows excess of bone formation.

whereas from the normal suture lines it can readily be wiped away. Blood may be seen escaping through a fissure. Torn periosteum must not be confused with a fissure of the bone.

A very common site of a direct depressed fracture of the vault is in the upper posterior part near the posterior fontanel. The region of the base

Fig. 11.—Depressed fracture of right frontal bone: *a*, Point toward vertex; *b*, anterior corner; *c*, lower outer end (Warren Museum, 4721).

Fig. 12.—Same from within; letters as in Fig. 11. Fracture shows depression without much new bone formation (Warren Museum, 4721).

(the posterior fossa and the foramen magnum), in which it is most dangerous for a fracture to occur, rarely is involved by an extension of the vault frac-

ture directly down to the base. The foramen magnum is wonderfully protected by strong radiating buttresses of bone. Fractures of the vault posteriorly generally extend forward into safe areas.

It is not an uncommon experience for the surgeon to be called to an individual who is unconscious following a blow upon the head. He finds a swelling on the top or side of the head. Palpation of the swelling may mislead him into thinking that a depressed fracture of the skull is present when only a hematoma of the scalp exists.

A hematoma of the scalp may suggest a depressed fracture of the skull (Fig. 13). The center of the blood-tumor is soft; the edges are edematous and hard. If the finger be pressed firmly into the soft center, an intact skull generally will be felt. The uniform edge of an hematoma is unlike the irregular jagged edge of a fracture. It is sometimes impossible to distin-

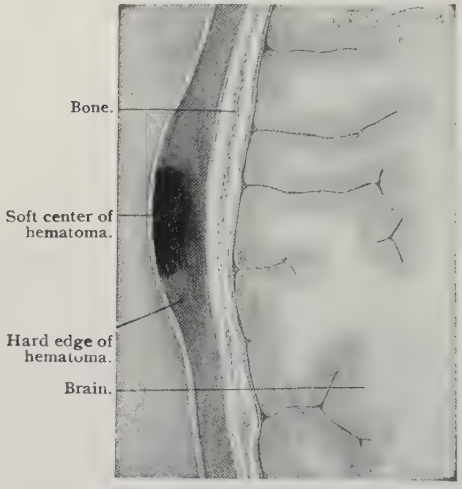


Fig. 13.—No fracture of skull. Hematoma of scalp, the soft center and firm edge of which often simulate fracture.

Fig. 14.—Punctate fracture entering posterior fossa. From the puncture depression a line of fracture extends downward and backward (Warren Museum, Specimen 965).

guish between an hematoma and a fracture of the skull by palpation alone. The symptoms of general disturbance are usually more marked and prolonged in the case of a fracture of the skull than when only an hematoma is present. If there is doubt after digital examination, properly taken stereoscopic *x*-ray plates will help to settle the matter.

Fracture of the Base of the Skull (see Figs. 19, 20).—It is not uncommon to discover that what in the vault appears to be a simple fissure continues down to and involves the base of the skull. Fractures of the base always follow the direction of the blow and never fall at right angles to it. This may be of assistance in medicolegal practice (Walton). Fractures of the base of the skull are usually regarded, and rightly so, as more serious than fractures of the vault. A greater trauma being necessary to cause the fracture, the cerebral disturbance is more pronounced and vital parts are en-

dangered. These fractures of the base often open into cavities which it is impossible to keep surgically clean, namely, the cavities of the nasopharynx and the ear. The danger of septic infection, therefore, in such fracture is

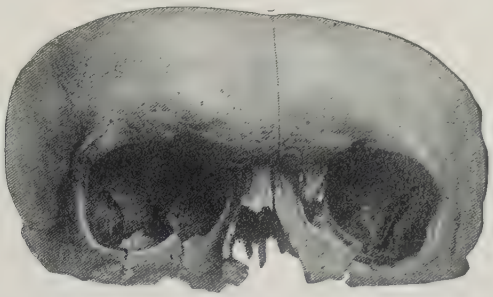


Fig. 15.—Anterior view of Fig. 16; note nasal bone depressed and driven into base of skull.

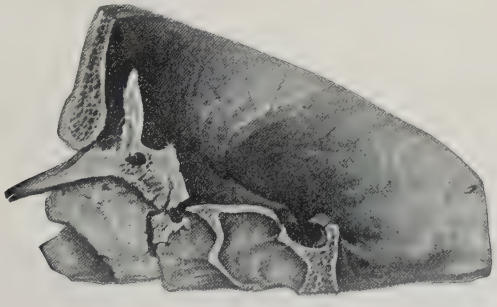


Fig. 16.—Fracture of base of skull; impaction of nasal and part of ethmoid bones, which project into the interior of cranium. Male, aged twenty-eight; diagnosis, fracture of nose. Died of meningitis (after Helferich).

very great. About 85 per cent. of basic fractures originate in the vault, *i. e.*, are caused by an extension of a linear fracture of the vault to the base. A few basic fractures are due to forces acting from below and thus causing

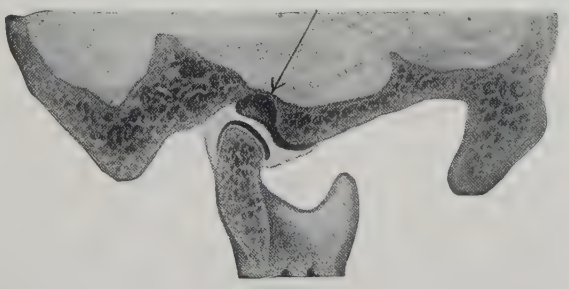


Fig. 17.—Showing thinness of the roof of the glenoid fossa, which is occasionally broken by the condyloid process of the inferior maxilla when a blow is received on the jaw. Arrow points to thin shell of bone between dura and joint below.

a penetration of the base of the skull by other bones. The facial bones may be forced up into the anterior fossa (Figs. 15, 16). The articular process of the inferior maxillary bone may be pushed up through the glenoid

fossa of the temporal bone (see Fig. 17) into the middle fossa by a blow upon the chin, particularly if the jaw is relaxed. This sometimes happens when a boxing blow is received on the chin. The vertebral column may be forced up into the posterior fossa through a fracture of the occiput occasioned by a fall upon the buttock.

Symptoms of Fracture of the Base.—Hemorrhage may take place from the ear, nose, and mouth, or be noticed under the conjunctivæ. Occasionally blood is seen in all four situations. Hemorrhage may occur beneath the pharyngeal mucous membrane. Escape of *cerebrospinal fluid* from the ear and nose may be noticed. Such escaping cerebrospinal fluid is a safety-valve against increased intracranial pressure. Brain tissue sometimes escapes from the skull and is seen lying in the external auditory meatus or near a wound which communicates with the fracture of the skull. Injuries may occur to the third, fifth, seventh, and eighth *nerves*. Associated with these local signs may be the general signs of concussion or laceration of the brain.

The behavior of the *pupils* is of importance. Lovett and John Munro found that the pupils failed to react in 39 out of 59 fatal cases of basal fracture in which the condition of the pupils was recorded. The pupils failed to react in only 1 of 12 cases, with recovery after basal fracture. Nichols found that in 54 cases of head injury with non-reacting pupils, 47 died, and that in the 24 cases diagnosed as basal fracture, all were fatal. This behavior of the pupil is very properly to be regarded as a sign of importance in studying these cases. Larger series of cases and better methods of investigation tend to modify the value of the pupillary reactions to light as a prognostic sign.

It is usually found that if unilateral dilatation and fixation of the pupil is present that it is on the same side as the intracranial injury or the hemorrhage following injury. Operation should be directed toward this side.

Attention is called to the importance of accurate and frequent observations of the pupil in patients who become unconscious as a result of head injuries, as they may well be a valuable aid in determining the side on which the operation for the relief of intracranial hemorrhage should be performed.

The importance of pupillary information in the absence of other localizing manifestations makes it imperative that its appearance be not prevented by the use of homatropin or other mydriatic drugs following skull injuries. The information available from a study of the eye-grounds can usually be obtained through the undilated pupil, and is, moreover, not to be compared in importance to that obtained from a unilateral paralysis of the third nerve, which may give evidence long before the development of papilledema, not alone of pressure, but also of its location.

1. Unilateral dilatation and fixation of the pupil is a valuable aid in determining the location of the intracranial injury and hemorrhage following head injuries.

2. Operative intervention should be directed toward the side on which this dilatation and fixation first appear.

3. Its transitory character makes accurate and oft-repeated observations necessary from the moment of injury.

4. The use of mydriatics should be avoided when intracranial trauma and hemorrhage are suspected following severe head injuries (Holman-Scott).

One pupil dilated and fixed, the other normal.[1] Many instances have been observed of dilatation and fixity of one pupil, while its fellow, perhaps with the exception of a little sluggishness of movement, remained normal. These were all cases of fracture of the middle fossa of the skull, and in comparatively few of them was the diagnosis verified by postmortem examination, though little doubt could exist as to the lesion when accompanied as they were by the usual phenomena of hemorrhage from the ear, followed by discharge of cerebrospinal fluid, ptosis, occasionally external strabismus, facial hemiplegia, and paralysis of members. In such the patient was generally insensible at the outset, when both pupils were dilated and fixed. As the patient recovered consciousness, one pupil became normal while the other remained dilated and fixed, this being on the side of the lesion. In some of these the visual power was on the same side

Injuries of Cranial Nerves Following Fracture of the Base of the Skull.—The order of frequency of injury is as follows: The facial nerve is most commonly injured, then the sixth or abducens, the auditory or eighth, the third nerve, the optic nerve. A permanent paralysis will follow complete division of these nerves. If the nerves are compressed by local or general edema then the paralysis will be temporary. If after a year the facial paralysis does not improve, it is wise to consider nerve anastomosis, *i. e.*, the hypoglossal or the spinal accessory with the peripheral facial.

Anterior Fossa.—If the *orbital plate* of the frontal bone is broken, blood will gravitate into the orbit; ecchymosis of the lids and subconjunctival hemorrhage will appear. There may be greater tension of the eyeball upon the affected side, detected by palpating the globe through the closed lid. Subconjunctival hemorrhage may appear from a fracture of the malar (outer wall of the orbit) or superior maxillary bones. Subconjunctival hemorrhage is not, therefore, an infallible sign of fracture of the base of the skull. A temporary motor aphasia may follow injury to the left frontal convolutions of the brain.

If the *cribriform plate* of the ethmoid is fractured, hemorrhage or the escape of cerebrospinal fluid from the nose will occur. Impairment of the sense of smell may exist if the olfactory nerves become involved in the fracture. Blood may trickle from a fracture of the base into the pharynx, be swallowed, and later vomited. Epistaxis, of course, may be due to a blow upon the face without fracture of the base. If inspection discloses a broken nose or ecchymosis of the face or the skin of the forehead, it is very probable that the minor accident has occurred.

Intracranial Aërocele.—Following fracture of the frontal bone—*i. e.*, through the outer and inner tables of the frontal sinus—air may enter the

[1] Macewen, William, The Pupil in Its Semeiological Aspects, Amer. Jour. Med. Sci., 94, 123–146, 1887.

cranial cavity. The presence of air within the skull cavity is called an aërocele. Bacteria may gain access with the air. The presence of an aërocele is determined by careful *x*-ray plates (Fig. 18) taken immediately after the injury and at intervals of from twelve to twenty-four hours. The aërocele may not appear until some hours after the accident. The importance of detecting an aërocele is that infection may follow unless the air cavity is exposed and thoroughly sterilized.

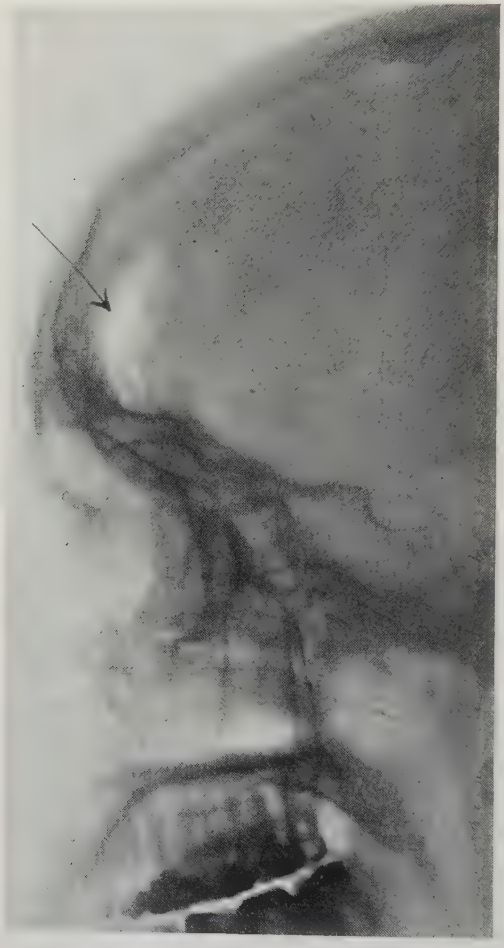


Fig. 18.—Intracranial aërocele following linear fracture of the frontal bone. Attempted drainage of septic intracranial focus did not prevent death from meningitis. Arrow points to aërocele. (Porter, Scudder, and Holmes.)

Middle Fossa.—Most fractures of the base involve the middle fossa. If the *petrous portion of the temporal bone* is fractured, several important signs are present. If the tympanum is torn, hemorrhage from the external auditory meatus is sure to follow. If this hemorrhage is continuous, it is significant; if it is trifling and temporary, it is probably unimportant and may be local. Cerebral tissue may escape from the nose, thus establishing the seat of the lesion. Cerebrospinal fluid may likewise escape from the ear. Cerebral tissue may also appear at the external auditory meatus. Any of these signs is conclusive evidence that the base of the skull is fractured and that there is a lesion of the brain. Lesions of the facial (seventh) and auditory (eighth) nerves lying within the bones occur. Lesions are likewise reported of the fifth nerve because of its lying upon the fractured petrous portion of the temporal bone. Subconjunctival hemorrhage may appear, owing to the blood working its way forward through the sphenoidal fissure and the optic foramen. The appearances of a "black eye" differ from a subconjunctival hemorrhage in that the former discoloration shades off into the tissues of the cheek, temple, and forehead (Stewart). A primary profuse watery discharge from the nose or the ear is probably cerebrospinal

fluid. A watery discharge appearing late after such an injury is likely to be serum from a blood-clot. The optic nerve may be involved in the injury, with resulting blindness.

About 37 per cent. of the fatal cases of fracture of the base of the skull die within six hours or less.

About 56 per cent. of the fatal cases of fracture of the base of the skull die within twelve hours.

The mortality of this group of cases can probably never be very materially reduced. They are primarily fatal cases.

Posterior Fossa (Figs. 19, 20).—If the posterior fossa is involved in the fracture, there may be hemorrhage into the pharynx. Fracture of the base

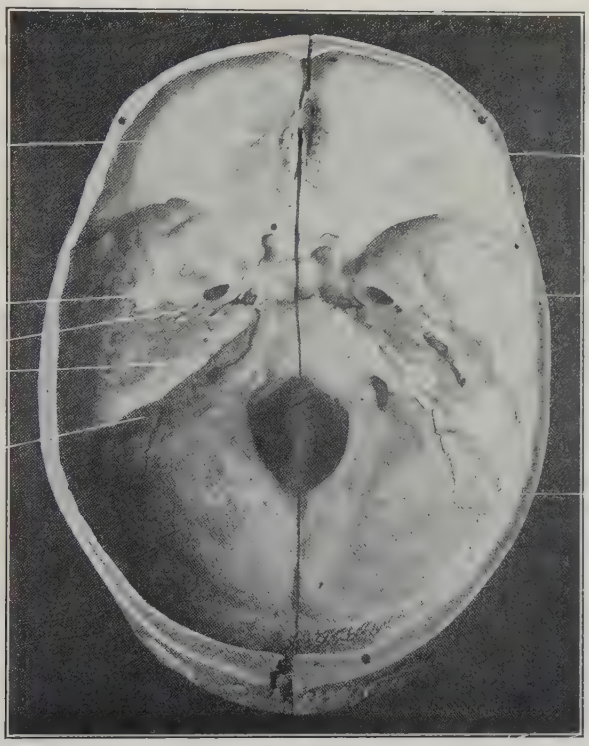


Fig. 19.—The three fossæ of the base of the skull viewed from above.

which opens the pharyngeal mucous membrane is occasioned by tremendous trauma. The pituitary fossa is fractured in such cases. The hemorrhage may be very considerable. The mortality of this form of fracture of the base is very high. Ecchymosis under the pharyngeal mucous membrane may be present without actual rupture of the mucous membrane. A fulness may be detected by palpation in the posterior wall of the pharynx if the hemorrhage there is considerable. Ecchymosis just in front of the mastoid process, or a hematoma and puffy swelling over the seat of the fracture, may determine its location.

Whether the fracture of the skull occurs in the vault, at the base, or wherever it may happen to be, the most important fact to be determined so far as the prognosis is concerned is what is the condition of the dura—has this barrier to infection been broken and opened?

Various Forms of Unconsciousness.—There are certain conditions associated with loss of consciousness and delirium which must be differentiated from the unconsciousness of traumatic intracranial lesions. These conditions are: (*a*) Unconsciousness attending severe shock; this shock should clear

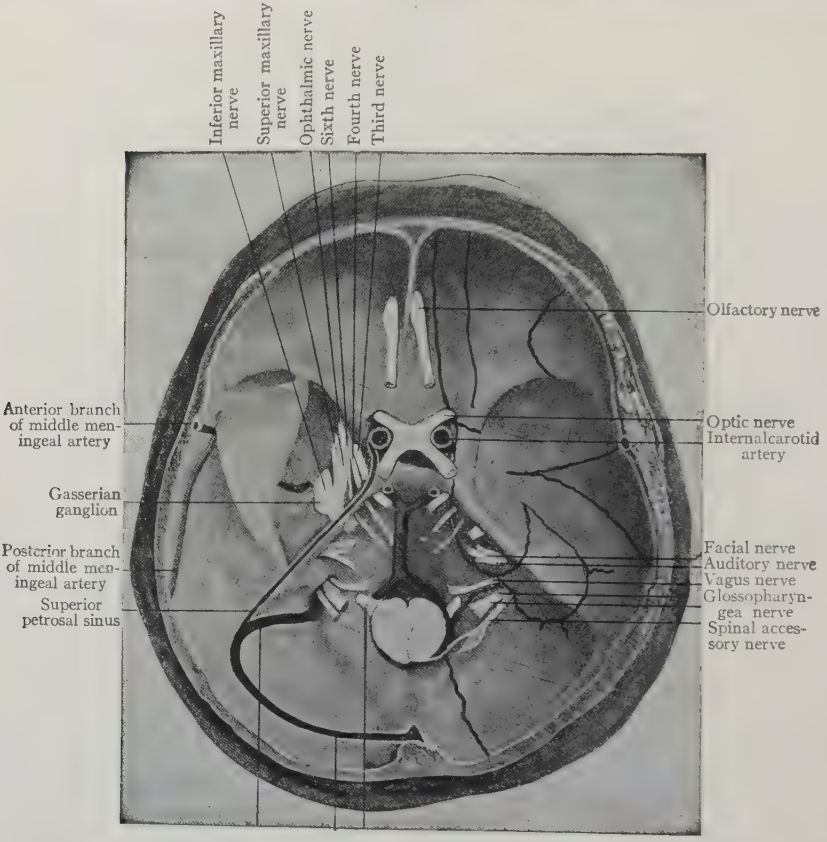


Fig. 20.—View of base of skull, showing relation of cranial nerves, carotid and middle meningeal arteries, and sinuses to the fossæ. This illustration shows on the right side of the skull the most frequent lines of fracture at the base of the skull (Eisendrath).

up in from four to eight hours at most; (*b*) the coma from opium poisoning; (*c*) the unconsciousness in uremia; (*d*) the loss of consciousness from apoplexy; (*e*) alcoholic coma, and (*f*) hemorrhagic internal pachymeningitis.

(*a*) *Unconsciousness from severe shock:* This has been considered elsewhere (see p. 19). It is mentioned here for completeness.

(*b*) *Coma from opium poisoning:* The patient can be aroused unless the poisoning is extremely profound, and can be made to understand, and will even reply to an inquiry. The face at first is pale, later it is flushed

and swollen. The skin is warm and moist. The respiration may become 6 to 10 per minute. The temperature is subnormal. The pulse is slow and full. The pupils are strongly, immovably, and symmetrically contracted —"pin-point pupils." The reflexes may be absent.

(*c*) *The unconsciousness in uremia:* The patient cannot be aroused. The face is white, edematous, and puffy. The breath has a sweetish odor. The respiration is frequent and irregular. The temperature is normal. The pulse is rapid. The pupils are dilated and sluggish. The urine usually contains albumin.

(*d*) *The unconsciousness from apoplexy:* The patient cannot be aroused. The face is flushed. The respiration is slow, irregular, and stertorous. The temperature is subnormal at first; if a fatal termination is probable, the temperature is high. The pupils are dilated. Unilateral paralysis of the face and of the extremities usually is present. The affected extremities are warmer than those of the other side. The limbs may be relaxed, but in watching the patient carefully evidences of hemiplegia will appear. The history of previous hemorrhages may be discovered pointing to hemorrhagic internal pachymeningitis.

(*e*) *Alcoholic coma:* The patient can be aroused by pressure upon the supra-orbital nerves—sometimes, however, with great difficulty. The breath may be alcoholic. The face is flushed. The respiration is regular. The pulse is rapid. The temperature is normal or low. The pupils are normal. There is an absence of the positive signs of a cerebral lesion. The temperature in cerebral laceration is elevated. Alcoholic delirium will present an elevated temperature, but along with the elevated temperature of a lacerated brain there will be symptoms characteristic of a damaged brain.

(*f*) *Hemorrhagic internal pachymeningitis:* The occurrence of apoplectic seizures during the course of this disease makes it important that it be recognized in connection with the distinctly traumatic hemorrhages under consideration. The characteristic course shows an acute diffused affection of the brain, usually in an elderly man, and with severe symptoms. An acute attack is followed by a fair recovery and by intervals of comparative health. During these intervals of comparative health the patient has some headache, slight diminution of intelligence, impairment of memory, drowsiness, partial paralysis of the limbs (usually unilateral), disturbances of speech, and sudden mental excitement without cause mixed with symptoms of paralytic dementia. Evidences of a sudden and increasing compression are headache, drowsiness, loss of consciousness, some fever, a pulse of compression, and sometimes initial symptoms of irritation. The diagnosis is assisted by the etiology and history of the case. In middle meningeal hemorrhage a blow is necessary to cause alarming symptoms, whereas in hemorrhagic pachymeningitis a very trivial injury or none at all is common. The longer duration of the symptoms would help to decide against middle meningeal hemorrhage. There is often a rigidity of the limbs in hemorrhagic pachymeningitis which is absent in middle meningeal hemorrhagic cases.

When called upon to see a case of head injury it must be remembered that the lesion cannot always be determined by the first observation of the patient. It is absolutely necessary that there be, upon the part of the physician, a clear understanding of the method of onset and the sequence of symptoms from the time of the receipt of the injury. Isolated signs are of less importance than relative symptoms. In so far as is possible these six causes of unconsciousness should be eliminated from the case in hand. It is, to say the least, discouraging to make a diagnosis of a serious intracranial lesion in an individual who is only drunk with alcohol or, vice versa, to suppose that a man with increased intracranial pressure from a middle meningeal hemorrhage is drunk. Careful examination and inquiry will go far toward avoiding such errors. In any case lumbar puncture with manometric measurement of the cerebrospinal fluid pressure is justifiable from the diagnostic and therapeutic point of view providing the stage of shock has passed.

If symptoms are subsiding, expectant treatment is advisable. If symptoms are increasing, reduction of the cerebrospinal pressure or operation is indicated.

A **diagnosis** must be based upon all available evidence. Cranial and intracranial conditions must be determined. The most important factor to be established is the presence or absence of *intracranial pressure*, its degree and progress. The second most important factor to be established is the presence and location and extent of a *fracture of the skull.* The third factor to be determined is the presence or absence of *associated lesions* in any part of the body other than in the head. One will have to consider concussion and laceration of the brain and pressure upon the brain by serum, blood, bone, and by a foreign body.

Lumbar puncture and the ophthalmoscope each offers a safe and accurate means of determining the presence of an increased intracranial pressure.

The use of these methods of examination requires careful training and considerable experience in properly interpreting the findings.

Lumbar Puncture.—The following precautions should be taken in a contemplated lumbar puncture:

(*a*) Withdrawal of the fluid slowly.

(*b*) An amount of fluid should never be withdrawn so as to reduce the cerebrospinal fluid pressure below a minimum average normal of 8 mm. of mercury.

(*c*) In original pressure readings of over 20 mm. of mercury fluid should be withdrawn to reduce the reading to one-half—*i. e.*, to 10—but never to a lower reading.

(*d*) If an original lumbar puncture pressure observation reaches such a height that it cannot be reduced to normal, then the lumbar puncture should be repeated during the following twenty-four hours; a decompression operation is to be seriously contemplated.

The normal pressure of the cerebrospinal fluid is 5 to 9 mm. by the mercurial manometer. The pressures over 12 mm. are pathological. The reading by manometer is more sensitive than the findings of the ophthalmoscope in low degree of pressure.

The presence of free blood in the cerebrospinal fluid at lumbar puncture is an added sign of intracranial injury, with or without a fracture of the skull.

The absence of the rose-colored fluid does not exclude an intracranial hemorrhage.

Lumbar puncture should not be performed during initial shock.

The therapeutic employment of lumbar puncture to remove cerebrospinal fluid and free blood must be very carefully guarded. Lumbar puncture is beginning to afford such uniform results that it is becoming a satisfactory form of treatment in carefully selected cases. If it is done slowly, with repeated manometric readings, it will be of very great value and will in certain instances obviate operative treatment.

A patient having high intracranial pressure immediately following injury may safely have lumbar puncture if certain precautions are taken.

Lumbar puncture may be used in mild cases of intracranial pressure, and repeated several times, often advantageously. A patient with an acute high intracranial pressure following injury should never be drained by lumbar puncture for fear of too great medullary compression at the foramen magnum; relief must be sought by operative decompression.

Ophthalmoscopic Examination and Findings (Sharpe).—The examination of the eye fundus following a severe head injury is a valuable method of measuring the intracranial pressure. The changes looked for in such an examination are the dilatation of the retinal veins and an edema recognized by a blurring of the margins of the optic disk. The term "choked disk" is applied to the blurred appearance of the whole of the disk—it is a sign of very considerable intracranial pressure. In a few cases of severe concussion the eye examination will reveal a dilatation of the retinal veins, that is, a mild degree of intracranial pressure. If there is an increasing intracranial pressure, then the change occurring in addition to dilatation of the retinal veins are a blurring of the nasal margin of the optic disk; then a haziness of the temporal margin; then a blurring of the nasal half; then an obscuring of the total disk or a choked disk.

Patients may be treated expectantly safely if only the first and less severe signs are present. If the ophthalmoscope finds a beginning papilledema then immediate operative relief of pressure is wise. The presence of shock in such patients precludes the appearance of intracranial plus pressure for about 6 degrees, except in primary massive hemorrhages.

The eyes should be examined regularly each hour following a head injury until the situation has cleared up.

In myopic individuals there is an obscuration of the disk outlines which must be taken into account in judging the importance of the ophthalmoscopic findings. It is suggested by Sharpe that these cases can be examined, if there is doubt, by the spinal manometer.

In contusion there is not likely to be a great subarachnoid extravasation, but in cases associated with more or less laceration of cortical brain tissue blood will be present in the subarachnoid space. A lumbar puncture should be made for purposes of diagnosis in all doubtful cases. If, as Cush

ing has pointed out, a patient has a high blood-pressure and is in shock of the third stage (see p. 21) of Kocher, it may be dangerous to draw fluid off by lumbar puncture; death is likely to occur. If in doing a lumbar puncture and withdrawing cerebrospinal fluid the pressure is not allowed to drop below a high normal for the individual under treatment there will be little danger. Subdural hemorrhage will be detected by lumbar puncture. Cushing first clearly associated blood-pressure changes with the degree of intracranial tension.

If the localizing signs are conflicting, they should be noted a few hours later, for they may change. Changing focal signs are of little value.

The *important signs to be studied in diagnosis* are the different aspects of unconsciousness; the relative and actual conditions of the respiration, pulse, and temperature; the occurrence of hemorrhage; restlessness and muscular twitching; localizing signs of pressure. If the symptoms are not positive, if there is no history of trauma, if the history of a lucid interval preceding unconsciousness is doubtful, or if there is no history at all, then the diagnosis will be most difficult. It is in the presence of unconsciousness when other positive symptoms are absent that one must particularly consider those conditions already mentioned in which coma is a prominent sign, namely, opium poisoning, uremia, apoplexy, alcoholism.

General Observations and Summary of Certain Well-recognized Facts.— Of primary importance is the discovery of the presence or absence of brain damage. After primary surgical shock has passed is increased intracranial pressure taking place?

Is increased intracranial pressure progressive?

Very severe brain damage may be associated with an intact skull.

Blows on the head severe enough to cause concussion do not always break the skull.

Concussion plus a scalp wound demands careful examination of the wound of the soft parts. A fracture of the skull liable to infection may exist.

Lines of fracture into the posterior fossa are most serious, for an increased pressure here may be limited by the tentorium and damage the medulla. In the presence of high intracranial pressure one should not delay operative treatment in order to secure *x*-ray or other evident signs of fracture.

An unconscious man having a scalp wound and a breath smelling of liquor is not necessarily drunk. He may have an intracranial lesion. Multiple lesions may be present in any case. A diffuse lesion may obscure a localized lesion. Not only must the location of a lesion be determined, but also its character, if possible. The symptoms must be recorded in the order of their appearance. The manner in which various symptoms develop should be noted. The danger to the brain is greatest in perforating and sharply depressed fractures. Slight fissures may be associated with extensive hemorrhages. Great comminution of bone may be devoid of much danger. In cases of compound fracture fissures apparently closed afford the possibility of cerebral and meningeal infection through dirt having entered when the fissure was open.

Unconsciousness and a *superficial head lesion,* with or without fracture of the skull, must make one suspicious of an intracranial lesion. *An immediate loss of consciousness* indicates a diffused contusion or concussion of the brain. If the primary *unconsciousness is prolonged,* probably hemorrhage has occurred, or possibly a serous exudation with its resulting pressure upon the brain.

If there is a conscious interval preceding the unconsciousness, a hemorrhage is probable. Momentary unconsciousness means concussion. Recurring unconscious periods indicate hemorrhage. *Deepening unconsciousness* indicates increasing intracranial pressure—probably hemorrhage. Immediate profound unconsciousness suggests hemorrhage from the rupture of an intracranial sinus.

The *temperature* in all intracranial lesions is usually slightly above normal. Intoxication and shock depress the temperature so that it may be subnormal. The other extreme of temperature, 105° F., occurs in the usually fatal edema of the medulla. Between these two serious extremes the temperature will vary considerably according to the conditions present within the cranium. To state these variations is a little speculative, but, in general, these observations upon the temperature are fairly accurate.

In a *small intracranial hemorrhage* there will be a slight rise of temperature, perhaps to 99° F., following the initial drop a few hours after the injury. In *cerebral laceration* one finds a higher initial temperature than in hemorrhage, and in fatal cases the temperature remains elevated. If the temperature rises quickly and early, a considerable laceration is present; if after several hours of unconsciousness the temperature remains about 99° or 99.5° F., there is probably *a hemorrhage* rather than a severe direct lesion if, on the other hand, the temperature rises higher, there is a cerebral lesion, alone or associated with a hemorrhage. If the temperature does not rise very high and advances rather slowly, there is *a contusion or a concussion* with slight laceration or a slight hemorrhage.

A slow, full pulse with stertorous respiration suggests pressure; it may be from extradural hemorrhage. Irregular (Cheyne-Stokes) and very slow respiration is associated with pressure upon the medulla.

Paralysis of the limbs and the face is characteristic of serous exudation, hemorrhage, or bony pressure. Irregular muscular contractions suggest laceration of motor areas. Mental disturbance may be due to cerebral lesions. That brain tissue escapes from the ear does not necessarily signify that the patient will not recover. Fractures of the base of the skull occur without marked symptoms and may be recovered from without operation.

Peculiarities of the child's skull must be considered in interpreting the lesion following trauma to the head of children.

1. The bones of the vault are very elastic: Trauma usually causes a bending of the bone over a considerable area. The large area of fibrous tissue between the skull bones prevents the transmission of force to the base of the skull from the vertex; hence basal fractures are rather unusual in children.

2. The diploë is absent. There is, therefore, no distinction between a fracture of the inner and outer tables; both tables are involved if either is fractured.

3. The air sinuses are absent or very little developed; this fact is of importance in injuries to the frontal region of the skull.

4. The greater adherence of the dura may help to prevent an extensive extradural hemorrhage. Very extensive linear fractures of the skull may occur in childhood. A natural decompression often results from the very great extent of the fracture if the dura is torn to a considerable extent. This natural decompression should not be depended on for treatment however. The efficacy of such decompression is extremely unlikely.

Treatment.—Following a severe head injury the primary object of immediate treatment is to save the life of the individual. The secondary object (and none the less important) is the restoration of the individual to a normal, sane condition.

The important indication for immediate treatment is the needed relief from an increased intracranial pressure, whether of local or of general extent. This increase of intracranial pressure may be due to a depressed fracture of the skull, to blood or to edema, or to an increase in cerebrospinal fluid. If the two former conditions exist, a local operation will suffice. If, however, a general edema exists, then a decompression operation by opening the skull will afford temporary and possibly permanent relief. Previous to doing a decompression operation magnesium sulphate or hypertonic salt solution should be used (see p. 43).

There are cases of injury to the skull so serious that it is evident that operation will be of no avail. These are cases of severe primary shock and of immediate medullary compression. There are cases of simple concussion, with or without fracture of the skull, in which only careful nursing is demanded. There is an increasing number of serious head accidents in which operative interference will prove of great value. A careful superficial examination will note fractures of the extremities, injuries to chest, abdomen, or pelvis, the presence of hemorrhage, or scalp wounds.

The Treatment of Shock.—The collapse from shock may be well-nigh complete, but restorative measures are not to be neglected upon this account. If hemorrhage is suspected, stimulation of the circulation must be very guarded. The patient should be placed horizontally, with the head slightly raised, and kept quiet. The whole body should be wrapped in warm blankets. Warm water bottles should be put on the outside of the bed about the patient, not next the skin, one at each foot, one between the thighs, three along each side of the body. The water in these bottles should be comfortably warmed—110° F. Hot water is never to be used. Patients under these circumstances are insensible to heat, and severe burning of the skin may occur if very hot water is used in the bottles.

The patient should be let alone after these preliminaries are over, and kept absolutely quiet. Pituitrin should be used: (*a*) to increase blood-pressure; (*b*) to increase cerebrospinal hypotension. Consequently, pituitrin

may be effectively administered in shock, and when, as occasionally occurs, too much cerebrospinal fluid has been withdrawn by lumbar puncture. Morphin should be used to secure quiet and rest. It must be constantly in mind that morphin quiets but at the same time depresses the respiratory medullary center. There is danger in obtaining too great depression. Rectal enemata of 3 ounces of black coffee given every four hours are useful.

Camphor in oil hypodermically is an available and safe stimulant.

If there are no indications for immediate operation, and localizing symptoms are absent, the patient is to be treated symptomatically. The pulse is to be carefully watched to detect variations in strength, rate, and rhythm. The character and frequency of the breathing are to be likewise noted. A special nurse or an intelligent watcher should be with the patient constantly to note any localizing signs of pressure, such as twitching of the muscles of the face or limbs and variations in the pupil, to record movements of the limbs, and to make hourly observations of the pulse, temperature respiration, blood-pressure, and any variation in consciousness. These observations will be of inestimable value in determining diagnosis, prognosis, and treatment.

So soon as the shock is decidedly lessened, when the pulse is about 100 and the general blood-pressure is between 100 and 120, then a complete physical and special neurological examination may be made safely.

As the shock diminishes, an enema of soapsuds should be given. If the patient happens to be conscious a cathartic (calomel $\frac{1}{2}$ gr. for several doses) may be given, followed by a saline laxative, such as phosphate of soda.

While in bed in the hospital an evacuating enema should be given each morning regularly. Moderate catharsis is helpful in the treatment of shock.

Remarks Concerning the Use of Hypertonic Solutions and Magnesium Sulphate.—In cerebral edema either hypertonic salt solution intravenously twice in first twenty-four hours, 60 c.c. each time, or a saturated solution of magnesium sulphate by rectum at twelve-hour intervals, or by mouth, are indicated.

If it is necessary to reduce considerably brain volume in a minimum time one should use an intravenous injection of hypertonic salt solution for a beneficial effect lasting a short period.

If it is necessary to reduce moderately brain volume for a beneficial effect over a prolonged time one should use a saturated solution of magnesium sulphate by rectum or by mouth.

In acute cases intravenous hypertonic solutions are probably not valuable unless they are given just previous to or during a decompression operation.

Dehydration may be produced by the excessive use of magnesium sulphate by mouth or by rectum—giving symptoms of a late onset of intracranial pressure.

The two conditions can be differentiated by lumbar puncture with manometric readings.

Associated with the condition of dehydration there is a demonstrable cerebrospinal fluid hypotension found at lumbar puncture as a reading much below the normal (Donald Munro).

Diet.—After two days, if the patient can swallow, a liquid diet may be used. If the patient cannot swallow readily, then nutrient enemata should be employed, together with rectal injections of warm water (6 ounces four times a day).

The various cavities exposing the brain to infection should be cleansed.

The *nose* should be cleaned by swabbing all visible blood-clot away and simply wiping carefully, and wisps of sterilized absorbent cotton should be placed loosely in each nostril. No spraying of or irrigation of the nasal chambers should be used. Albolene applied to the nostrils will soften accumulated crusts. It is important not to produce a sneeze, for septic material may be driven into the middle ear or ethmoidal cells and may be the cause of a septic meningitis (Cushing).

The *ear* (*i. e.*, the external auditory canal) should be wiped with boric acid solution (1 : 30) and dried carefully with small wisps of cotton. A bit of sterilized gauze or absorbent cotton may be left loosely in the external auditory meatus. Great care must be used to avoid making a plug or obstructive dressing of the absorbent cotton.

The Scalp.—The directions for cleansing the scalp apply to cases with or without scalp wounds associated with important cerebral symptoms. The whole scalp should be shaved, scrubbed with hot water and green soap, if the scalp is greasy or oily, with chlorinated soda solution (1 : 20), with boiled water, and then with alcohol (70 per cent.) or benzine, and lastly with tincture of iodin full strength, and covered with a dressing of sterilized gauze. A careful débridement of the scalp wound should be done. The wound of the soft parts should be carefully irrigated with sterilized salt solution. The swabs used should be tiny ones, so as to reach the smallest recesses of the wound.

The Mouth.—Cleaning with an alkaline (alkalol or its equivalent) solution the teeth and tongue and all the folds of the mucous membrane about the lower and upper jaws is important. The swabbing of the tonsils and the posterior pharyngeal wall, the care of the nose and the ear—these procedures will reduce to a minimum the chances of infection. The nose and mouth will require constant attention. The ear may require at least daily inspection in order to keep it dry and free from crusts and blood. The frequency of the cleansing required will depend very largely upon the amount of moisture and discharge from the part involved. If the cotton wisps soon become moistened, the cleansing should be repeated, and fresh, dry cotton replace the old.

If there is great restlessness, the administration of small repeated doses of morphin (gr. $\frac{1}{8}$ hypodermically) is indicated. It may be necessary to restrain the patient that he may not harm himself. This is done by means of a folded sheet passed about the bed and body of the patient.

These cases of *suspected fracture of the base* are to be very carefully watched. They should be kept in bed for two or three weeks, quietly resting, so that any existing fracture may heal. The patient is ignorant of the potential immediate and remote danger from a basal fracture. He cannot appreciate

the importance of rest. Rest should be enforced. The patient recovering from such a severe head injury should have a prolonged rest and keep away from very laborious or active work for at least four months or even a year (see p. 49). When the patient is allowed to go from the care of the surgeon he should be sent to the family physician, with careful statements of the condition and with specific instructions as to treatment in the immediate and remote future (see p. 49).

Compound Fracture of the Skull.—A wound of the scalp communicating with a fracture of the skull challenges the surgeon's technical skill perhaps as much as anything he may have to encounter. His success in the treatment of such a wound will be in proportion to the scrupulous care exercised. The entire scalp usually should be shaved. The scalp should be cleansed with soap and water, rinsed thoroughly, dried, and tincture of iodin applied. The wound itself should be freed from gross dirt and irrigated with salt solution. A local anesthetic should be used whenever possible—novocain with adrenalin. The scalp wound should be encircled so as to cut away the edge completely. The skull in the neighborhood of the fracture should be perforated by small trephine holes so placed that when they are joined by cuts through the skull the broken bone mass may be lifted out as nearly in one piece as possible.

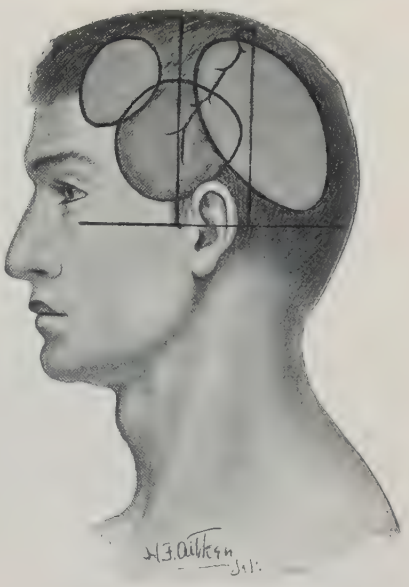


Fig. 21.—Sites where extradural hemorrhage is usually found.

The edges of the torn dura should be carefully excised. The damaged cerebral tissue should be cleaned with salt solution. If there is a deep wound of the brain, catheter suction (Cushing) should be employed to remove débris, lacerated brain tissue, blood-clot, and bits of foreign material. Drainage should be employed in the presence of a possible infection. Drainage is ordinarily unessential for ordinary slight oozing of blood.

The question of covering the dural defect and the repair of the cranial defect are important matters that I have not space to discuss here. In general it may be said that if the likelihood of sepsis is remote it will be wise to attempt a primary closure of the cranial wound, *i. e.*, dura and scalp.

Operative interference is demanded in penetrating or sharply depressed fractures, in all compound fractures, and in all simple fractures with symptoms of intracranial hemorrhage increasing in severity or distinctly localized (Figs. 21–23). A trephining operation *per se* is devoid of great risk.

Operation is necessary after skull fracture if there are present the signs of *an advancing lesion*, despite the previous use of hypertonic saline solution or lumbar puncture.

Drowsiness or stupor may be caused by cerebral concussion and may last for hours. If stupor becomes deeper and evidences of intracranial pressure appear, surgical interference is undoubtedly indicated.

Immediately following a head injury there may be a weakness or *paresis* of one or more extremities. Such symptoms do not demand immediate operation. On the contrary, if these symptoms progress, and later complete paralysis of an extremity appears, and if convulsive twitchings develop, operation will be necessary. The presence of paresis in an extremity should

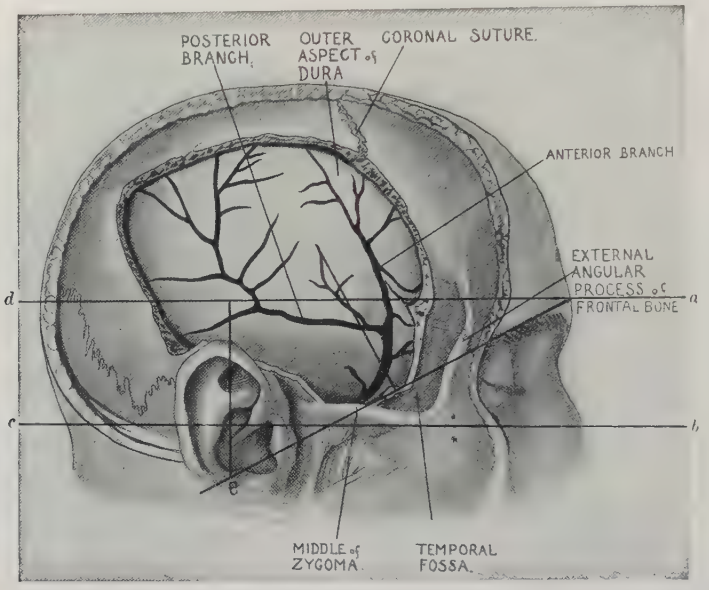


Fig. 22.—Location of *anterior* branch of middle meningeal artery. Draw a line from the glabella backward (*a–d*), parallel to the line *b–c*, from the lower edge of the orbit through the external meatus. Line from glabella to mastoid, *a–e*. From the middle of this last line, a line drawn perpendicular to it will intersect the line *a–d* at about the site of the artery. A line running from the front of the mastoid perpendicular to the line *b–c* intersects *a–d* at about the site of the posterior branch (after Eisendrath).

make one cautious, and repeated examinations of the patient should be made. The paresis will point to a focal lesion.

If a *hemorrhage from the middle meningeal artery* is suspected and the removal of the bone upon one side of the skull does not discover a hemorrhage, the skull should be trephined upon the opposite side. All the blood-clot that can be removed with ease should be wiped away with a smooth blunt instrument or gently washed away by a stream of warm salt solution. If bleeding from the artery cannot be checked by ligation of the vessel because of its inaccessibility, it may be controlled by absorbent cotton pledgets soaked in hot salt solution packing. The use of Cushing's dura clips and small bits of temporal muscle tissue as "packs" will help to stop bleeding. No gauze

or absorbent cotton packs are to be left *in situ* unless absolutely necessary. This packing should be removed at an early hour subsequently, so as to avoid the intracranial pressure caused by the presence of the gauze. If the bleeding is from the bone it may also be stopped by the use of sterile wax, and if it is from the middle meningeal artery it may be stopped by plugging the foramen spinosum with a bit of sterile orange-wood stick. If the bleeding is from a sinus or some unrecognizable source, gauze or absorbent cotton packing will check it. Great care should be exercised that the gauze or cotton tampons are all identified or removed before the end of the operation.

Operation should be undertaken in these cases for these distinct reasons: to insure cleanliness, to elevate and, if necessary, remove bony fragments, to remove blood-clot, and to check hemorrhage. Further details of operative treatment must necessarily be omitted from this limited space.

If the pulse gets below 60 and the respiration gets below 16; if the blood-pressure reaches 140 or over; if there develops a definite optic disk haziness or even edema; if the spinal fluid pressure by manometer exceeds 16 mm. of mercury; if there is, too, a paresis or paralysis anywhere, operative treatment is necessary. Some decompression operative procedure is indicated.

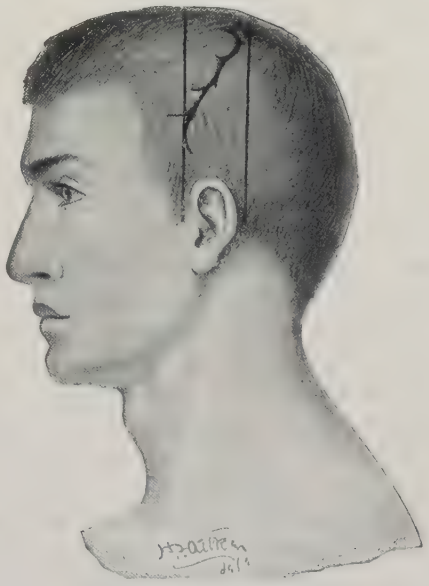


Fig. 23.— Perpendicular lines from the mastoid and from just in front of the ear include the motor area of the central convolutions. The fissure of Rolando is shown.

All cases of injury to the head, even cases of simple non-depressed fracture of the skull without symptoms, are to be watched with great care by trained observers for at least one month following the accident, and then are to be seen at intervals for several months afterward. The reason for this prolonged observation is that meningeal hemorrhage may develop in the immediate future, and that after an interval of months a brain abscess may manifest its presence, and, perhaps most important of all reasons, the danger of chronic brain lesions developing is to be carefully watched for, so that suitable treatment may be instituted at an early date. Intellectual workers require twice as long a time for convalescence as manual workers (English).

In the case of a primarily and often a secondarily unconscious person with fracture of the base of the skull and an increased intracranial pressure an operation of decompression upon the right side, according to Cushing's suggestion (1908), is to be employed. The vertical incision—splitting the muscle, with a horizontal incision extending forward or backward according to the situation of the cranial fracture—is the incision most satisfactory.

The opening made in the temporal region by splitting the temporal muscle, removing the squamous portion of the temporal bone, exposes the region of the meningeal artery. The bone is very thin in this region. The dura should be opened. The wound if closed without drainage leaves a musculocutaneous covering. If any drain is left it should be a thin rubber tissue drain. It should be left for a few hours only. This procedure may relieve intracranial pressure effectually. In a certain series of basilar fractures so treated the mortality has been decidedly low (Jason Mixter). Always consider in a case of basilar fracture the wisdom of a Cushing decompression operation. Even if there is no unconsciousness and the symptoms are increasing, a subtemporal decompression should be done. A middle meningeal hemorrhage can be reached through a temporal decompression field. The tips of the temporal and frontal lobes are most often disturbed. These parts are accessible through a temporal decompression.

Obviously, if there is present a hematoma in the occipital or mastoid region, indicating a serious *lesion of the posterior fossa*, any decompressive operation should seek to relieve the increased tension beneath the tentorium. A subtentorial trephining should probably never be done for an acute trauma. The danger and difficulty attending it are too great. Trephining the skull above the level of the tentorium will probably not relieve the subtentorial pressure very materially. In fact, if there is subtentorial increased pressure a decompression above the tentorium may do actual harm by suddenly changing intracranial pressure relations. Following contusion or laceration of the posterior fossa contents blood tends to gravitate into the region of the cisterna magna which, interfering with the cerebrospinal fluid circulation, will create a temporary external hydrocephalus. This latter condition can be attended to by the supratentorial approach.

In the consideration of the necessity for operation in head injuries one must constantly keep in mind the very great importance of avoiding a symptomological approach to the medullary edema stage of intracranial compression. The stage of very severe shock, on the one hand, and of medullary edema, on the other hand, mark the viable limits of an individual. Within these limits life is just possible.

Irritative or paralytic focal symptoms pointing to pressure upon or disorganization of definite cortical areas are most important indications for operative interference.

For isolated or irregular disturbances of neurological function conservative forms of treatment will yield the best results.

Prognosis.—A *concussion of the brain* must have a circumspect prognosis attached to it both immediately and remotely. Edema of the meninges and brain may follow a simple concussion and prolong the convalescence, even giving rise to compression of cranial contents and focal symptoms. Prolonged mental depression and severe headache may follow concussion. The prognosis of head injuries is the prognosis of their complications and sequelæ. Prolonged unconsciousness is not usually dangerous in itself.

Late unconsciousness is dangerous. The late development of coma, indicative of recurring extradural hemorrhage, cerebral edema, or infection, may appear following a subdural bleeding, particularly of pial origin. The severity together with the form of the lesion is to be made the basis of prognosis.

When there is a fracture through the anterior fossa there is danger of septic infection through the nose because of the fracture of the horizontal plate of the ethmoid.

There is a great mortality attending fractures of the base of the skull associated with much bleeding from the nose.

If the middle fossa is fractured, infection may arise through the nasopharynx and ear; the middle meningeal artery may be torn or the carotid artery lacerated.

If the fracture involve the posterior fossa, venous sinuses may be damaged.

The prognosis will vary, therefore, according to *the fossa* involved in the fracture. Apparently, the mortality increases as the injury moves from before backward. The mortality is least when the anterior fossa is fractured, greater when the middle fossa is fractured, and greatest when the fracture is through the posterior fossa. The proximity of the medulla and vital centers to the fracture in the posterior fossa increases the mortality very appreciably.

Observations of many fractures of the base lead one to place considerable importance in the *pupillary reactions* in determining the prognosis of these cases. If the pupils fail to react (*i. e.*, dilatation of the pupil with absolute fixation) the prognosis is grave. Failure of the pupils to react following a basilar fracture is almost always a fatal sign. The *temperature* is of great value in prognosis. By its persistent depression the danger from primary shock is gauged; a little later in the course of the case the amount of hemorrhage is judged by it; later still, its rapid and progressive rise will denote the magnitude or severity of a meningeal or cerebral lesion. A temperature as high as 105° F. is of grave prognosis. This elevation to 105° F. has been called the "temperature dead line," so fatal are cases under these conditions. A sudden rise of temperature late in the progress of a case, probably due to meningitis, or a continued subnormal temperature at any time after the reaction from the primary shock, always are unfavorable signs.

There is great doubt as to the outcome of traumatic lesions, particularly during the first few days after the receipt of the trauma. The prognosis may have to be altered each succeeding day to correspond with changed conditions. A most serious situation following a head injury may clear up unexpectedly. A case apparently progressing satisfactorily may assume suddenly a grave aspect. The prognosis must, therefore, always be guarded.

Convalescence Following Cerebral Injury.[1]—Convalescence following brain injury may properly be said to commence at any time from forty-eight hours up to three weeks after receipt of the injury. It may be defined as the time during which the patient no longer requires active surgical intervention of any sort.

[1] This convalescent program was arranged by and is used by Dr. Donald Munro, Boston.

First Period.—The onset of the convalescent stage is simultaneous with the return of the intracranial pressure to normal. This may be evidenced by a return of the pulse to its normal rate, the regaining of a natural mental condition, or by finding with the aid of a manometer the cerebrospinal pressure itself normal.

The essential therapeutic element during the convalescent period is rest. While the cerebral mechanism is still in the early stages of recovery from injury this rest should approach as nearly as possible the physiological. This requires a minimum of excitement, a quiet room, avoidance of eye-strain. Finally, and most important of all, the patient should be kept flat in bed. The reasons for this are: First, it is possible to keep the patient quieter in this position than in any other, and second, this is the position which is least likely to cause any abnormal increase of cerebrospinal pressure. This first period should extend over ten days regardless of the wishes of the patient and regardless of the apparent improvement which is taking place. The following four days the patient may sit up in bed for increasing periods of time if no symptoms are caused thereby. This two-weeks rest in bed is essential regardless of the previous treatment or the extent of the injury.

Second Period.—Convalescent care after two weeks is as essential for complete symptomless recovery as the care given immediately following the injury, and, like that given during the first two weeks of the convalescent period, just described, has for its chief therapeutic element rest. It differs, however, in that a constant effort is being made to graduate downward the amount of rest and simultaneously graduate upward the amount of physical exercise.

The first six to ten days following the initial two-week rest period, as described above, are given over to getting the patient out of bed and walking about the hospital preparatory to returning to his home. At the end of this time he is discharged from the hospital with the following written instructions, and with the clear understanding that he is to obey the directions given exactly as they are written:

This schedule is to be followed exactly unless instructed otherwise by your own doctor If you start your day at 8 A. M. instead of 7 A. M. advance each "time" given below one hour so that the intervals will all remain the same lengths as originally planned.

7.00 A. M.:	Get up.
7.30 A. M.:	Breakfast.
8.00–11.00 A. M.:	Out of doors with some sort of moderate exercise. Short walks, work in a garden, automobile rides, golf, etc., are suggested.
11.00–12.00 NOON:	Lie down and rest. You need not sleep, but you must be lying down and not sitting up.
12.00–1.00 P. M.:	Dinner or lunch.
1.00–4.00 P. M.:	Your time. In so far as possible it is advisable to use this time out of doors with some sort of moderate exercise.
4.00–5.00 P. M.:	Lie down and rest. This corresponds to the rest period in the morning.
5.30 P. M.:	Supper or dinner.
9.30 P. M.:	Bed. At least nine hours or, better, ten hours *must* be spent in bed, whether or not you sleep.

GENERAL DIRECTIONS

Do Not:

1. Drink any form of alcohol.
2. Take any medicines except on the direction of a doctor. (If you have been accustomed to taking cathartics before your injury, you may make an exception to the above with this medicine only.)
3. Get cold or wet. If you are cold put on more clothing or bed covering. If you get wet, change to dry clothing at once.
4. Get overtired.
5. "Loaf."

Sleep with the windows of your bedroom *wide* open *every* night.

Eat plenty of plain food three times a day and not oftener.

Drink 2 glasses of water with every meal, and more in between meals if you want it.

Smoke only half as much as you did before your accident.

Bowels must be kept regular.

If you want to recover in the shortest possible time you will follow this schedule exactly as written for one month unless your own doctor changes it. At the end of the month report for examination to your own doctor or consultant that further treatment may be outlined for you.

If at any time you think you are not getting along as well as you should, report at once to your own doctor. Do not wait to see whether or not you are going to get better anyhow.

Third Period.—This phase of the convalescent care occupies one month. At the end of that time the patient is examined, and if progressing satisfactorily is told to return home and follow the directions as before with the following exceptions: 1. He is to omit the morning rest hour. 2. He may take as much physical exercise as he wishes, provided he does not decrease the amount, and provided that it is carried on out of doors.

This third phase also should be continued for one month, and another examination made at the end. If the patient has been steadily improving physically, and if nothing new neurologically has developed, he should be instructed to omit entirely the restrictions under which he has been living for the past two months, and in their place return to his normal habits of life with the exception that he is to work only on a half-time basis.

Fourth Period.—This is to last for another month, following which he is to return to his original job and to forget that he has ever sustained an injury.

This convalescent treatment may be summarized as follows:

1. *Convalescent period* begins with the return of the intracranial pressure to normal.
2. *First Two Weeks of Period.*—Flat in bed in a quiet room.
3. *Third Week.*—Up and about in hospital.
4. *Second Month.*—At home on convalescent schedule.
5. *Third Month.*—At home as before, but with physical exercise increased in amount.
6. *Fourth Month.*—Normal life. Half-time job.
7. *Fifth Month.*—Normal life. Full-time job.

Students' Summary.—(*a*) Recognize the symptoms and signs of shock in all head injuries.

(*b*) Treat the shock.

(*c*) Base further treatment upon the early recognition of the presence or absence of increased intracranial pressure.

(*d*) Operate upon all depressed fractures of the vault of the cranium, whether intracranial pressure symptoms are present or not.

(*e*) Increased intracranial pressure is to be measured by the general and local signs enumerated and confirmed by the intelligent use of the ophthalmoscope in studying the eye fundus, and by the careful use of the manometer after an aseptic lumbar spinal puncture.

(*f*) Whether operation should be done or not in a given case will depend upon the answer to the question: Is the intracranial pressure observed immediately after the recovery from initial shock diminishing, stationary, or increasing?

The Reduction of Increased Intracranial Pressure.[1]—The old empirical treatment for head injuries consisted of rest in bed, morphin, and large doses of magnesium sulphate.

The value of this treatment has been confirmed and its use established by extensive clinical application.

For oral administration 3 ounces of a 50 per cent. solution of magnesium sulphate has given excellent results. Six ounces of a 50 per cent. magnesium sulphate is used for rectal administration.

The *slow* reduction of increased intracranial pressure in the absence of shock, hemorrhage, vomiting, or dehydration is satisfactorily accomplished by the oral or rectal administration of magnesium sulphate. The *rapid* reduction of intracranial tension in acute intracranial traumata unassociated with shock is best accomplished by the intravenous administration of hypertonic saline solution. Glucose may be given later to maintain the lowered intracranial pressure.

Hypertonic glucose solution administered intravenously is indicated when acute intracranial pressure is associated with shock or hemorrhage, and in the less acute cases when complicated by dehydration, nausea, and vomiting.

Glucose seems to have the following advantages over any of the salt solutions: prolonged action, no terminal rise in pressure, non-toxicity, non-dehydration, increased blood-volume in shock, and the control of acidosis.

LATER RESULTS OF INJURIES TO THE HEAD

That certain remote effects results from trauma to the head is becoming more evident as larger numbers of persons are examined by competent observers months and years after injury. The paper by English (see Bibliography) is notable, and the following facts are of importance. A knowledge of these remote consequences of head injury is important both clinically and medicolegally. A man is never quite the same after a severe head injury (English).

Unfortunately, immediate recovery from a head injury may not always imply permanent health. Of 200 injuries of the head carefully followed

[1] Conclusions of M. M. Peet, Ann Arbor.

by English after apparent immediate recovery 39 per cent. showed no effects afterward, 46 per cent. showed slight signs of trouble which did not seriously deter from earning a living, 14 per cent. showed marked symptoms which prevented the individual from working. In over 10 per cent. of the cases there existed some degree of mental impairment.

Before deciding that any symptoms or group of symptoms is to be attributed to a definite head injury it is important to know whether such symptoms have occurred in this individual previous to the accident. The accident may have no causative relation. A malingerer must be detected. Several examinations upon successive days should be made for the sake of accuracy.

The following are found to be some of the later effects of head injuries:

Chronic headache, which may be *general*, over a large (frontal, occipital, etc.) area of the head, or *local*, corresponding to definite scars in the scalp, or to tender areas upon the skull, or neuralgic-like, along the course of certain nerve trunks. Along with these chronic headaches are associated insomnia, mental depression, loss of appetite, inability to do any work, lack of energy, and a characteristically marked aspect. At times painful and tender cicatrices in the scalp are discovered, which are significant.

Vertigo occurs in many cases, and is often very persistent.

Vomiting is associated with headache and vertigo.

Changes of character appear. Persistent depression and melancholy are evident. There is often great mental irritability. The individual "loses his nerve." An increased susceptibility to the effect of alcohol is not uncommon. An inability for mental and physical exertion is prominent. There is disturbed sleep. The high climatic temperatures are quickly felt. Sunstroke is common.

The following conditions are enumerated as having been noted in a study of these cases. Motor aphasia, traumatic amnesia, agraphia, loss or impairment of the arithmetical faculty and the muscial faculty; certain lesions of the cranial nerves are often noted after head injuries which help to localize the fracture or injury to the brain, such are: loss of smell when the cribriform plate is broken; inequality of the pupils; accommodative asthenopia; nystagmus; facial paralysis, although several cases of paralysis of the seventh nerve have eventually completely recovered; deafness; glycosuria and hemiplegia are both recorded as closely following injury to the head.

In order to avoid these unpleasant after-effects of head injury, or at least to minimize them, it is essentially important that sufficient *mental rest* should be observed following the apparent early recovery. A forced mental rest is important (see p. 49). It should be insisted upon by the attending physician. No head injury, however trivial, should be regarded as unimportant and be made light of to the patient or the patient's friends. *Trephining* of the skull, when any local indications of bone cicatrix or scalp cicatrix are present, may reveal changes in the dura and underlying brain which, by

excision or because of the change of pressure occasioned by the exploration, will cease to be irritative lesions.

Chronic cerebral abscess may follow slight trauma to the head with almost unnoticed cerebral disturbance. Becoming walled off from the brain tissue the abscess may act like a brain tumor, and if it chance to lie in a silent portion of the brain causes no symptoms until months or years afterward, when drainage of such a focus will probably relieve the situation permanently.

Traumatic epilepsy is another undoubted and unfortunate result of injury to the head. Probably few cases of traumatic epilepsy would exist if all depressed bony fragments were thoroughly elevated at the time of the original trauma. It is estimated that epilepsy follows skull fracture in about 5 per cent. of the cases. Epilepsy follows fracture of the vault of the skull more frequently than fractures of the base of the skull. What cases of traumatic epilepsy are suitable for operative interference? There must be evidence of a definite injury, the epilepsy must be localized—*i. e.*, Jacksonian—in type; the individual should not have suffered for more than two years, and there should be no decided neurotic family taint. Under these conditions operation may afford relief for a few months or even so long as three years, but rarely for a longer period. During this period the bromids and luminol should be administered.

Insanity.—Mental impairment is not uncommon after head injuries, yet the degree of change from the normal individual is rarely so great as to include it under the heading of insanity.

Insanity may result, however, from injury to any part of the head. Those cases of traumatic insanity which present a localizing indication are likely to be relieved by operation; and in only this class is operation justifiable. The results from operation in suitable cases are satisfactory. The alternative, if no operation is done, is hopeless in the extreme.

Dr. Bullard, of the Boston City Hospital, has contributed so valuable a paper upon this subject that the results are here stated: Seventy patients were examined after having had fracture of the skull; 37 presented no symptoms when examined some time later. The most frequent consequences were headache, deafness, dizziness, and inability to resist the action of alcohol on the brain. Out of 15 cases in which operation (trephining) was performed, 12 had no resulting symptoms; in one case it was doubtful whether the symptoms present were due to injury; in one case the symptoms were slight (headache rare, tension over the wound while lying in bed). The other case was deaf, but had no other trouble.

Dr. Bullard concludes, so far as these statistics lead, that those cases in which cranial operation was performed have shown much better results, so far as the symptoms previously mentioned are concerned, than those in which no operation was performed. This conclusion is corroborated by the accumulated experiences of recent years. There is greater freedom from chronic posttraumatic cerebral symptoms after a decompression operation than without such operation.

CASES OF HEAD INJURY

The following cases, related in some detail, illustrate a few of the varieties of injuries to the head from a clinical standpoint:

CASE I.—*A fall upon the head. No visible evidences of injury. An interval of consciousness followed by unconsciousness. Localizing signs of pressure. Diagnosis: Middle meningeal hemorrhage with fracture of skull. Operation. Fracture and hemorrhage found. Recovery.*

M. A. B., sixty-nine years old, a spinster, fell, upon being struck by a coasting-sled, one and one-half hours previous to the examination.

Examination: She does not know of the accident which has befallen her. She talks coherently. She recognizes her sister. There is slight shock. The pulse is 64 and of fair strength; the respiration is 16; the temperature is 97.5° F. There is bleeding from the right ear. There is some dry blood about the nostrils. There is no visible external injury. There is no paralysis. All the superficial reflexes are present. The pupils are contracted equally and react to light. The patient is not very restless, although she talks considerably and affirms again and again that she is not hurt.

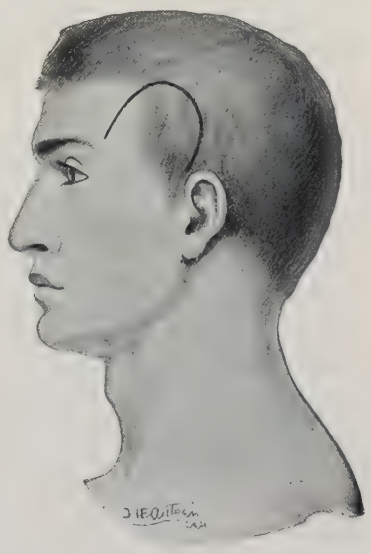


Fig. 24.—Case I. Line of incision shown.

The ears were washed out carefully and treated antiseptically.

She vomited two or three times during the night. She was quite restless, moving and turning in bed. She slept two or three hours altogether. There were no evidences of intracranial pressure in the morning. At about noon of the second day she talked a little incoherently. She did not answer questions as readily as in the morning.

At 3 o'clock in the afternoon of the second day examination finds the pupils equal and reacting to light. She understands what is said to her, but does not talk coherently or distinctly. There is almost complete paralysis of the right arm. There is paresis of the right leg. The face is not paralyzed. The pulse has increased in rate to 85 and is particularly full and bounding. The knee-jerk is much less active upon the right than upon the left side.

At 4.30 P. M., one and one-half hours after the previous observation, all the symptoms were considerably intensified. The face was uneven, the wrinkles being most marked on the left. The breathing was becoming labored and almost stertorous. It was hard to arouse the woman. She moved the left arm freely. The right arm she moved slightly or not at all. There were no abdominal reflexes active. Bleeding from the right ear continued to a slight extent all day.

A diagnosis of middle meningeal hemorrhage on the left side was made. Immediate operation was decided upon.

Under ether anesthesia an elliptic incision was made upon the left side of the head, beginning just in front of the ear, and was carried up across the temporal muscle and down to the zygoma of the same side. A $\frac{1}{4}$-inch trephine was used. The hemorrhage was found to be from a branch of the middle

meningeal artery, and from within the dura, which was lacerated. A large clot and much fresh blood were lying over the temporal and parietal regions. This blood was carefully sponged away. The middle meningeal branch was tied with a silk ligature. Gauze wicks were placed deep toward the base of the skull. The dura was not sutured. The bleeding vessels of the diploë were stopped with wax. The skin flap was replaced and sutured, leaving a small gauze drain down to the dura.

The pulse was poor, and there was evidence of considerable shock at the conclusion of the operation. Proper stimulation with strychnin and enemata of salt solution and brandy had a good effect. The temperature rose to 110° F. during the night, but dropped immediately, and gradually came to normal.

The following day unconsciousness was present, the paralysis was unrelieved, the breathing was stertorous and puffing.

The second day after the operation the gauze drain was removed and two smaller gauze drains were inserted. Some signs of consciousness appear. She takes notice of people coming into the room.

The fifth day following the operation she notices friends. The paralysis is still present.

The sixth day after the operation she moves the right leg a little. No articulate speech is present. Understands questions and grunts in answer to all questions. She can express no idea in words.

The tenth day after the operation she moves the right arm. The mental condition is clearer.

On the eighteenth day she moves the right leg, and the arm has more power.

The thirtieth day was an important one for the patient. She walked alone for the first time since the accident.

One year after the accident the patient is found to be having occasional attacks of dizziness, accompanied by "falling fits." She is perfectly sane, and talks, often very well; then there come times of difficulty in talking, when she cannot find the right word to express herself. Just after one of these attacks of fainting, etc., talking is less easy.

Three years after the operation the following conditions were found: The speech is thick, slow, and with effort. The facial muscles of the left side are stiff and slightly drawn; they do not move so well as on the right side. The left nasolabial fold is more accentuated than the right. The left eyebrow is lower than the right. The patient thinks that she can hear better with the right ear than with the left. The right hand gets cold "and does not look natural." The right forefinger is often whiter than the other fingers of the right hand. It is difficult to pick up needles or pins with the fingers of the right hand. There is no increase in the wrist-jerks. The knee-jerk is slightly greater on the right side than on the left.

The patient says she is enjoying excellent health, eats and sleeps well, and is out of doors much of the time. She is taking bromid of potassium regularly once a day in small doses. About once a month she has a fainting or "weak spell." These attacks are growing less pronounced and less frequent.

This case illustrates the important fact that after a severe head injury with almost no external visible sign, the patient should be kept under very careful observation through the hours immediately succeeding the accident. Relative symptoms are of far greater importance in head injuries than isolated observations. Bleeding from the ear as a symptom in head injuries does not necessarily imply fracture of the petrous portion of the temporal bone. Rupture of the tympanum may cause bleeding from the ear. There was no fracture of the skull detected after careful examination in this case.

The interval of consciousness in this case was a somewhat short and hazy one. Immediately after the accident the woman was dazed, and at no time was she herself mentally. It is to be remembered in this connection that the interval of clear consciousness may be so masked by the symptoms of concussion as to be completely overlooked.

CASE II.—*An open depressed fracture of the skull. Absence of unconsciousness. Paralysis of one-half of the body. Operation. Recovery.*

This case illustrates that consciousness may be unimpaired following an injury to the head severe enough to cause paralysis.

A boy, nine years old, was struck on the head by a brick falling from a height. He was seen immediately after the injury and found to be conscious. He answered questions naturally. There was a large scalp wound over the parietal bone and a little anterior to the parietal eminence to the right of the median line. The bone beneath the scalp wound was fractured and depressed into the brain substance. The left arm and the left leg were completely paralyzed to motion. The right pupil was dilated; sensation was present. The right upper eyelid drooped. There was a scar in the right cornea. Immediately after the injury the temperature was 96° F., the pulse was 74, the respiration was 26. When examined one hour after the accident the pulse had fallen to 68, he had vomited once, and had been somewhat nauseated.

Fig. 25.—Case II. Open depressed fracture of the skull: *X*, The midpoint between glabella and inion; *A*, middle of depressed bone.

The operation of elevation of the depressed fragments of bone was done under ether. The fragments of bone removed were about the size of a silver half-dollar. There was no fissure in the skull. The dura mater was torn and the brain slightly lacerated. Upon elevating and removing the depressed bone hemorrhage occurred from the vessels of the dura mater. The depressed bone was not replaced. The dura was left open and the cavity was drained by a wick of gauze, which was removed upon the third day.

A few hours after the operation the boy was perfectly conscious as before the etherization, the pupils were normal, and motion had returned in the paralyzed limbs.

Three weeks after the operation a small, granulating wound remained and there was a slight tendency to hernia cerebri.

Four months following the accident the boy's condition is as follows: The wound is nearly healed and continues to discharge at times. He walks naturally. There is no paralysis of arm or leg. No mental symptom is present.

The interesting and unusual fact in this case is that after a blow sufficiently severe to cause a depressed fracture of the skull and paralysis of one-half of the body the patient remained conscious.

The exact location of the injury to the head and brain is shown in Fig. 25.

CASE III.—*A blow upon the head. Unconsciousness immediate. Slight bulging of right eye. Middle meningeal hemorrhage. Fracture of skull. Operation. Recovery.*

Examination found edema of the right temporal region. Unconsciousness present. An interval of consciousness was absent. Slight bulging of the right eye.

Operation in the right temporal region. A skin-flap was made over the fracture and edematous area. A fracture was detected running from about the middle of the temporal ridge an inch back of the coronal suture outward and forward across the squamous part of the temporal bone to $\frac{1}{2}$ inch behind the pterion.

The bone anteriorly to the fracture was depressed. The trephine was applied over the depressed portion behind the coronal suture. Upon exposing the dura no pulsation was seen. The dura was dark in color. A slight amount of extradural blood escaped. On following the fracture down to the base of the skull the dura was found lacerated, the anterior branch of the middle meningeal artery was torn, and blood-clot and lacerated brain tissue were present. The anterior branch of the middle meningeal artery was tied and the hemorrhage ceased. The blood-clots were removed, the

Fig. 26.—Case III. A fracture across squamous portion of temporal bone. Middle meningeal hemorrhage. Operation. Recovery.

exposed area was cleansed with boiled water, and gauze drainage introduced. All the gauze was removed in four days. No unusual symptoms attended convalescence. Recovery was complete in three months (Fig. 26).

This case is of interest because no fracture was detected before the operation, and it was supposed that the bulging of the eye indicated an increase of intracranial pressure, which proved to be true.

The method of operating was comparatively simple, in that the fracture was followed down until the bleeding vessel was found. This necessitated the free removal of bone below the trephine opening.

There was no interval of consciousness in this case, and the conditions found easily explained its absence. The man was suffering from concussion and laceration of the brain as well as from intracranial pressure, and the interval of consciousness was obscured by the presence of the concussion. The recognition of an interval of consciousness is of very great importance. If, however, the interval of consciousness is not present, as in the case reported, intracranial pressure from hemorrhage cannot be said to be absent,

for concussion attendant upon the injury may mask the interval of consciousness which might have been present had the injury been less severe.

Case IV (Quoted by Crandon and Wilson).—*An injury to the head. Unconsciousness. Bleeding from ear. Consciousness returns. Five days later walks about. Sudden death.*

A soldier from a harbor port was found on the sidewalk after a fall from assault or accident. Unconscious; bleeding from left ear, hematoma behind it; left pupil larger than right, but both react sluggishly; no paralysis. Consciousness returned in a few hours, bleeding stopped, the pupils became normal, and the patient was quite without symptoms on the third day. On the fifth day, against advice, the patient insisted on leaving the hospital, boarded the steamer, and reached the fort. He stepped ashore and dropped dead. The autopsy showed a fracture of the base of the skull.

This Case IV is quoted to emphasize the very great importance of proper rest after a serious trauma to the head. (See paragraph under Treatment, p. 49.)

CHAPTER II

FRACTURES OF THE BONES OF THE FACE

Anatomy of the nasal bones—The nasal septum—Treatment—The malar bone—Treatment.

FRACTURES OF THE NASAL BONES

Anatomy.—The anatomical relations of the nasal bones (to the perpendicular plate of the ethmoid, the vomer, the cartilaginous septum, the superior maxillary bone, and the frontal bone) make their fracture of far greater importance than a mere superficial disfigurement of the face would indicate (Fig. 27). The site of the fracture is often near the lower edge of the bone.

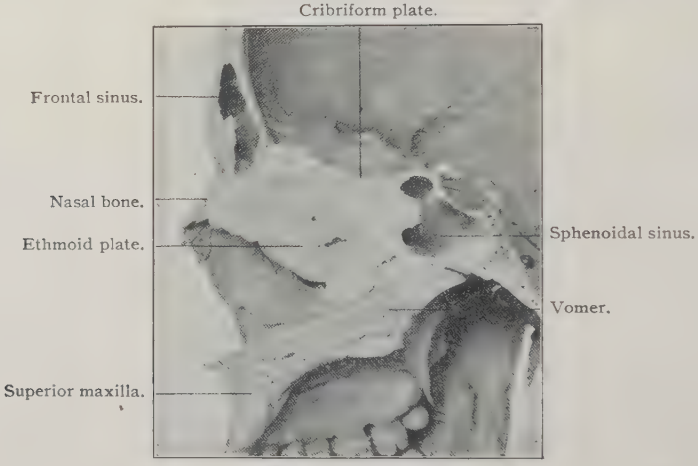


Fig. 27.—Median section of nose.

Most fractures of the nasal bone are open through either the skin or the mucous membrane. In nearly all nasal fractures the cartilage of the septum is more or less injured. The upper lateral cartilages may be torn from their attachments to the nasal bones, simulating fracture of these bones. The resulting deformity of this accident is well illustrated in Fig. 28. A high fracture of the nasal bones with lateral deformity is shown in Fig. 29; the nasal bone of one side has been impacted with the frontal bone, and the nasofrontal articulation upon the opposite side has been separated. The nasal bone that receives the fracturing blow is broken from its connections and is depressed below adjoining bones (see Fig. 39). The nasal bone on the side opposite the blow is sprung out from its connections and overlaps them. The nasal bones are separated, therefore, from proper connection with each other, with the frontal bone, and with the nasal process of the superior maxillary bones. These facts must be kept in mind in attempting reduction of

fracture of the nasal bone. Figures 29 and 31 show a case in which, by a direct blow squarely upon the nasal bones, the bones were separated and one was laid on one nasal process of the superior maxillary bone, and the other was laid upon the corresponding bone. The septum was intact, as is

Fig. 28.—Separation of cartilage from nasal bones (Harrington).

Fig. 29.—Fracture and lateral displacement of each nasal bone.

shown by the persistence of the natural position of the tip of the nose. Figures 32 and 33 show a syphilitic nose, the septum gone and the nose fallen in. The contrast in these two latter cases is instructive.

Fig. 30.—Case of fracture of nasal bones. Lateral displacement (Harrington).

Fig. 31.—Fracture and lateral displacement of each nasal bone. Side view of Fig. 29.

Symptoms.—Pain, swelling, crepitus, and deformity are usually present. The subcutaneous swelling is often so considerable as to obscure deformity. Gentle pressure is often sufficient to detect crepitus in this fracture, when a firm grasp determines little or nothing.

Complications.—Through infection of the internal or the external wounds suppuration begins, abscesses form, and necrosis of bone and liquefaction of cartilage may occur. Emphysema may be noticed if the fracture is open into the nasal cavity (Fig. 34). It will disappear after a few days untreated.

The lacrimal duct may be obstructed if the nasal process of the superior maxillary bone is involved. The nasal bone may be forced up into the floor of the anterior fossa of the skull, and cerebral complications arise (see Fig. 16). If the deformity following fracture of the nasal bones is not corrected there is great likelihood of trouble, either immediately or in after years, because of the damage to the nasal septum.

The Nasal Septum in Fracture of the Nose (Figs. 35–39).—The starting of the quadrilateral cartilage of the septum at some of its bony attachments

Fig. 32.—Syphilitic deformity (Harrington).

Fig. 33.—Syphilitic deformity (same case as Fig. 32).

may be evident at once after the fracture of the nose as a marked dislocation, or no change may be seen until long afterward, when a ridge due to inflammatory thickening is found along the previously loosened border. The septum may be dislocated from its attachment to the superior maxilla, and deviate into one nostril or the other like a curtain. The commonest dislocation occurs at the junction of the cartilage of the septum with the vomer and the ethmoid.

Lesions of the septum due to fracture occur usually in the posterior two-thirds of the cartilaginous and in the anterior half of the bony septum. Fractures rarely extend through the septum to the posterior nares. In fractures of the nasal bones with little displacement the septum may show no changes. Even with considerable depression and comminution of the nasal bones the septum as a whole may appear unchanged, the lesions of

the septum being confined to bowing or tearing at the seat of fracture. When the nasal bones are much deviated the free edge of the septum deviates with them. Fractures of the nasal bones may occur alone or in combination

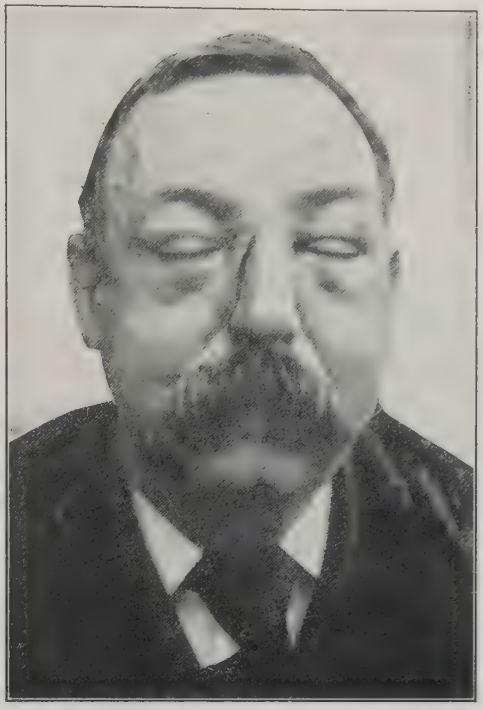


Fig. 34.—Case of open fracture of the nasal bones. Emphysema over the forehead and the upper part of the face.

with fractures of the septum. Severe cases of broken nose usually combine the two conditions. Fractures of the septum which admit of classification follow one of two types—horizontal fractures or vertical fractures. The

Fig. 35. Fig. 36. Fig. 37. Fig. 38. Fig. 39.

Figs. 35–39.—The septum in fractures of the nose (Mosher).

vertical fracture is much the rarer. It may occur anywhere in the course of the cartilaginous septum, but when situated well back is to be distinguished from dislocation of the cartilage. The horizontal fracture produces a gutter-like deformity roughly parallel with the floor of the nose. The convexity

appears in one naris, the concavity in the other. Closely allied to these last two fractures are the sigmoid deviations, in which the relation to fracture is unsettled. They are so common that they are mentioned for the sake of completeness. The name describes them. They occur in the same two types as the angular variety.

Treatment.—The nasal cavity should be inspected by mirror and light to determine any lesion of the septum. Cocain anesthesia is necessary for this examination. If a deviation is found, it should be corrected along with the correction of the external nasal deformity. For this primary anesthesia will be needed, as the manipulation is extremely painful. By external manipulation combined with elevation of the fragments and internal pressure (Fig. 40) the deformity can be overcome. That nasal bone which received the trauma must be elevated and the opposite nasal bone must be separated from the superior maxilla. This is accomplished in the following manner

Fig. 40.—Fracture of nasal bones. Elevation of depressed bone by instrument introduced into the nostril.

Fig. 41.—Cobb's splint applied to a case of fracture of the nose. The head-band is so adapted to the shape of the head that it remains fixed and offers a point of counterpressure.

(Mosher): A flat elevator is placed in the nose well up under the depressed nasal bone; the thumb of the left hand is placed against the second nasal bone where it overlaps the ascending process of the superior maxilla. As the elevator raises the first bone and forces it outward, the second nasal bone is raised also by the traction in the skin and periosteum, so that its outer edge is unlocked from the ascending process of the maxilla. Meantime, thumb pressure forces this last bone into the median line. In this manner both bones are replaced in their normal positions. Any strong, narrow, and thin instrument will be of service as an elevator. For fractures high up with displacement, gauze packing carried well up may be required to retain the elevated bones. For lower deviations the *Asch tube* may be needed. If the nose is crushed it will be necessary to model the nose over the Asch tube, one being placed in each nostril, to preserve the contour and lumen of

the nose. If there is no tendency for the deformity to recur, the use of splints is not indicated. Care must be exercised by the patient to avoid sudden pressure on the nose from the rough use of the pocket handkerchief. In the treatment of these cases special cleanliness, perfect drainage, and frequent dressings are important. If there is a recurrence of the external deformity, localized pressure may be exerted in various ways, all of which are more or less unsatisfactory.

The tin splint fixed to the forehead by a circular plaster band is of service. This tin splint, made from ordinary sheet tin, consists of a forehead and a nasal portion molded to the forehead and to the sides of the nose. The nasal portion may be twisted or bent laterally to secure the desired pressure upon the nose, the counterpressure being obtained through the fixation secured by the adhesive plaster band to the forehead. Repeated adjustments of this splint are needed to make it of continued efficiency; with all care, however, the tin splint does not generally prove effective.

The use of adhesive plaster strips (after Davis) from cheek or malar bone region to nose with small compresses is of limited value.

Cobb's nasal splint, shown in Fig. 41, is expensive, but is very satisfactory for making direct pressure upon the nasal bones. The splint is made of a band of steel, fitted to the head like the hat-band of a hat. To this band are attached an arm and a pad with screw adjustment. A strap over the head and one beneath the chin prevent downward and upward displacement. (See Eisendrath's modification of this splint of Cobb in Keen's Surgery.)

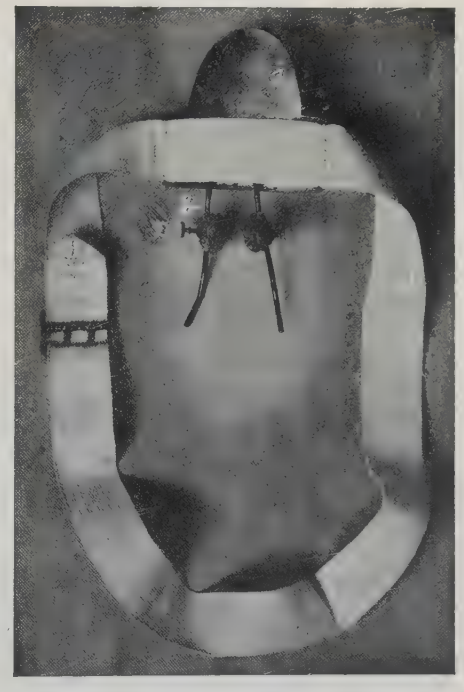


Fig. 42.—Coolidge's nasal splint: *a*, Forehead plate; *b*, pad; *c*, screw controlling position of pad; *d*, head-strap.

Coolidge's Splint (Fig. 42).—This consists of a tin pad for the forehead with strap encircling the forehead for the retention of the pad in position. To the lower border of the pad are soldered two wire arms upon which slide two small felt pads. The arms can be bent so that counterpressure may be obtained upon the firm parts of the face, while direct pressure with the other pad is brought to bear upon the nose. This splint is inexpensive and is efficient.

The nasal cavity should be cleansed at least twice daily with antiseptic douches. Seiler's tablets, one tablet dissolved in a quarter of a tumbler of warm water, used with the Birmingham glass douche, make a satisfactory

wash. The external wounds should be dressed according to general surgical principles (see Compound Fractures). It is well to remember in this connection that suppurating wounds do far better if dressed frequently than if left to accumulate purulent discharges.

After a blow upon the nose, even if there is no immediate deformity, the nose should be examined to determine the presence of swelling upon the cartilaginous septum. Even a slight blow upon the nose may cause a hematoma of the cartilaginous septum. This hematoma is liable to become infected and to suppurate. Considerable destruction of cartilage may follow, resulting in marked disfigurement of the nose.

The involvement of the base of the skull adds a serious element to an ordinarily simple accident (see Fig. 16).

The **prognosis** as regards the resulting deformity must always be guarded. Union usually takes place within two weeks of the accident and is firm in one month. In treating fracture of the nose it is important to be ever mindful of hematoma of the septum, and of abscess of the septum resulting from the hematoma and of deviation of the septum. The external deformity that follows fracture does not tend to increase, but the internal deformity does. It is, therefore, of importance to correct the internal deformity as well as the external. Unless the internal deformity is corrected the nose may be straight, but obstructed. A physician especially skilled in the care of the nose should be employed to attend to the conditions existing inside the nose following fracture of the nasal bones.

Old Fractures of the Nasal Bones.—The usual internal method of employing a saw for dividing the nasal bones from within the nose and the mallet blow from without is less accurate and satisfactory than the direct external method of Mosher for correcting the lateral deformity of the nasal bones following old fractures.

Mosher's description of this method is clear and concise, and follows:

An incision $\frac{1}{8}$ inch long is made in the skin over the lower outer angle of the nasal bone. A chisel to fit the incision is placed in it and then driven through the bone with a mallet. The chisel is then pushed up, carrying the skin before it, and again driven through the outer border of the nasal bone. When this has been done the third or fourth time the top of the nasal bone is reached. The chisel is then turned horizontally so that it is parallel with the edges of the teeth and at right angles with the incision through the outer border of the nasal bone and driven inward through the root of the nasal bone. The operator is able to accomplish this extensive chiseling of the bone through the one small skin incision because the skin over the nasal bone, as one can readily test on himself, is displaced upward very readily. It can be displaced downward but little. The same procedure is repeated on the other nasal bone. The horizontal incision through the root of the nasal bone should be especially thorough, otherwise the nasal bones will not be freed sufficiently to give good results. This is a point where the internal method is especially inadequate. The mallet is depended upon to fracture the root of the nasal bone. The line of the fracture which this

gives is not definite and often not free enough. Both of these objections can be done away with by a thorough use of the chisel in the external method. When the nasal bones are sufficiently cut through they are forced into the

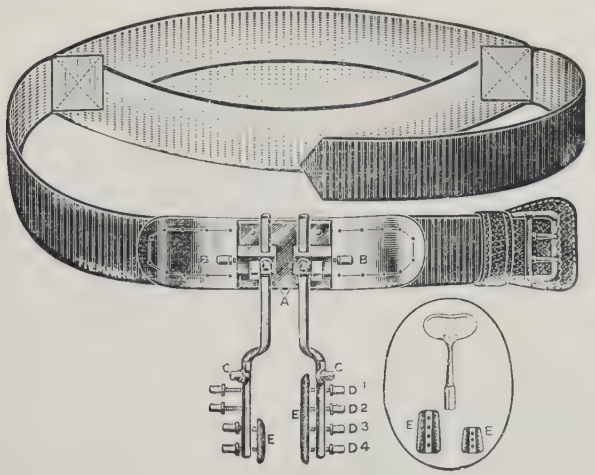


Fig. 43.—Nasal splint of Berne. Adjustment inward, upward and downward, and anteroposteriorly by screws *A* and *B*. Rotation accomplished by rods controlled by *C* and *C*. Uniformity in pressure is secured by adjusting screws 1, 2, 3, and 4. (Jour. Amer. Med. Assoc.)

middle line by a pair of septum forceps or by the fingers. If they do not start readily the mallet may be used.

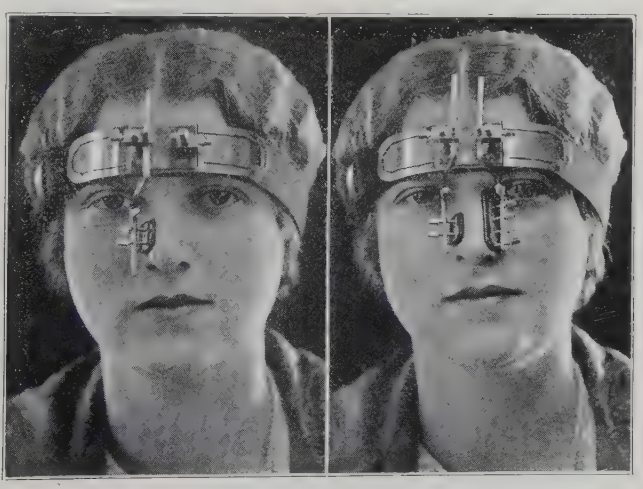


Fig. 44.—Berne's adjustable splint for fracture of nasal bones. Note use of the clamp *A* when unilateral pressure and immobilization are needed. Note also possibility of securing bilateral pressure. (Jour. Amer. Med. Assoc.)

When the nasal bones have been replaced in the middle line it will be found in a majority of cases that the ascending process of the superior maxilla on the side toward which the bones originally deviated is so prominent

that it will cause a marked deformity if it is left in its present condition. This deformity is due to the growing together of the displaced nasal bone

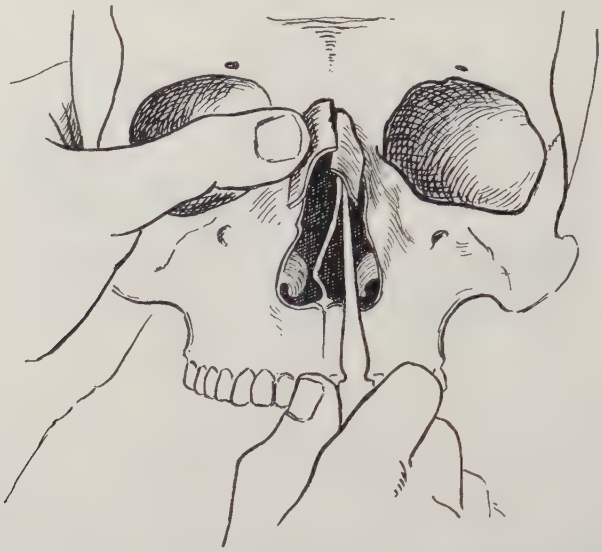


Fig. 45.—A type of a marked fracture of the nasal bones. The trauma was received in the left nasa bone primarily. Note the left bone depressed, impacted with frontal and possibly with nasal process of left superior maxilla. Note the right bone elevated, separated from its attachments. Note septum unattached in middle line and deviating in lowest part to right side. Note positions of thumb and elevating instrument (after Mosher)

and the ascending process of the superior maxilla. This deformity is easily remedied by replacing the chisel in the skin incision, forcing the skin out-

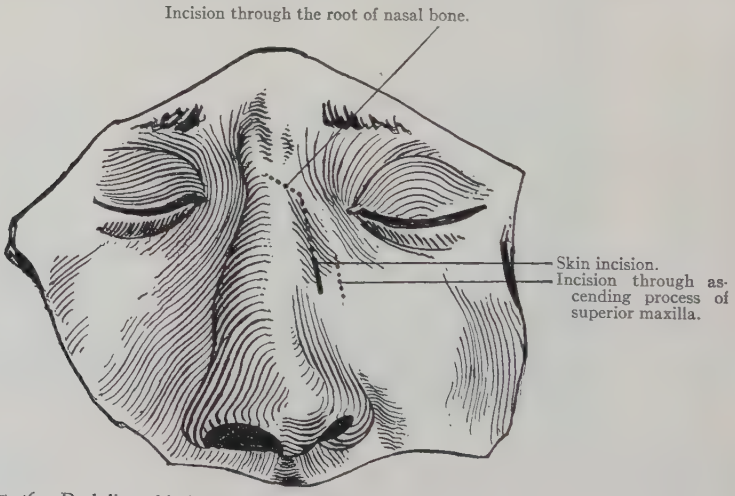


Fig. 46.—Dark line, skin incision; dotted lines, bone incisions (Mosher).

ward as far as is necessary, and then cutting off the projecting part of the ascending process with one or two cuts of the chisel. Occasionally the ascending process on the other side may require the same treatment. It is

necessary to treat the ascending process on both sides in the case of a wide nose which is to be narrowed.

The treatment of the cartilaginous deviations within the nose may be primary at the time of the correction of the bony deformity or, in certain intractable cases, secondary. If, as Mosher suggests, the packing necessary to maintain the connected septum in good position interferes with the replaced nasal bones, causing their displacement, then the secondary treatment of the septum after the nasal bones have healed will be best.

FRACTURES OF THE MALAR BONE

Examination.—Palpation of the malar bone is somewhat difficult. The best method of doing it is to stand behind the sitting patient (Fig. 47), and to feel both malar bones at the same time—the left one with the left hand, the right one with the right hand. The malar process of the superior maxilla is felt inferiorly by pushing the skin of the cheek upward. The orbital part of this process is felt superiorly at the middle of the inferior border of the orbit. Following the orbital margin outward and upward, the orbital border is palpated up to the frontal process. Following the malar process of the superior maxilla backward, the free inferior border of the malar is felt continuous backward with the zygomatic process. Starting on the frontal process, the posterior border of the malar may be palpated downward and backward to the upper border of the zygomatic process of the temporal bone. The inferior surface of the malar may be felt by placing the fingers, palm upward, in the superior sulcus of the cheek and following backward until the coronoid process of the lower jaw is felt. In the case of a fracture that is as often unrecognized as is this one it is important to be very familiar with the details of the outline of the bone.

Fig. 47.—Proper position from which to palpate the malar bones. The fingers touch the inferior borders, the thumbs the posterior borders, of the malar bones.

Fig. 48.—Depressed fracture of the left malar bone. Note swelling of the left cheek and slight hollow outside of the left orbit (Warren).

Symptoms.—Fracture of the malar bone is caused by a severe blow upon the cheek. It is rather unusual to find a fracture of the body of the

Fig. 49.—Depressed left malar bone. Same case as Fig. 48. Note depression behind and below left orbit (Warren).

bone. More often there is a fracture of one of its processes, the line of fracture being continuous with a fracture of some adjoining bone. The malar

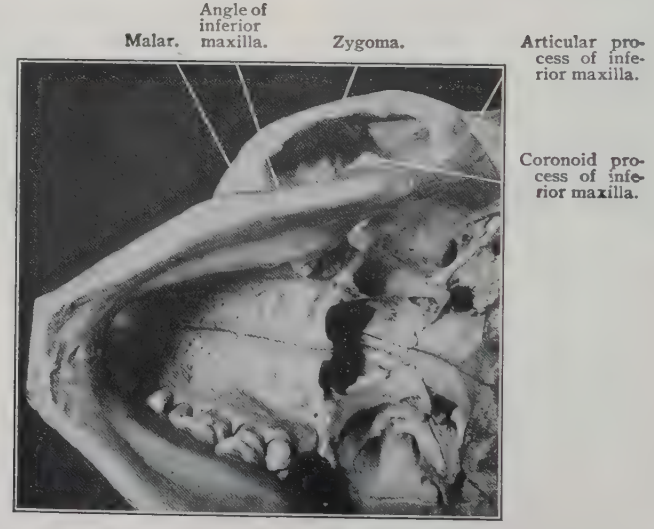


Fig. 50.—View of skull from under surface. Note relations of coronoid of inferior maxilla to zygomatic process and malar bones; the space on either side of the coronoid process is filled by muscle.

is depressed as a whole, or tilted inward toward the zygomatic fossa because of a loosening of one or more of its articulations or because of a fracture

or crushing of the superior maxilla. The deformity consists of a depression to the outer side of and below the eye. The line of fracture or separation can sometimes be palpated. Mobility and crepitus are rarely obtained. If the depression of the malar or of an associated fracture of the zygomatic arch impinges upon the space in which the coronoid process moves in the opening of the mouth, the motions of the lower jaw will be restricted (Fig. 50). The limitation of motion of the lower jaw may be temporary or permanent, depending upon whether it is due to hemorrhage and swelling or bony pressure. The coronoid process of the lower jaw may be fractured by the same force which fractured the zygoma or malar. Localized subconjunctival hemorrhage may appear if the orbit is involved. If the floor of the orbit is fractured so that the infra-orbital nerve is implicated, there will appear prickling sensations throughout the area of distribution of that nerve, namely, along the upper gum, the skin of the cheek, of the nose, and of the upper lip; and there will appear a subconjunctival hemorrhage.

Treatment.—It is sometimes impossible completely to correct the deformity except by operative means. If any interference with the movements of the lower jaw persists after the acute swelling disappears—that is, after two weeks—or if it is very evident at the outset that the limitation of motion is due to the depression of bone, then operative interference is demanded. Before a cutting operation is resorted to an anesthetic should be administered and an attempt made by pressure with a blunt instrument under the malar from inside the cheek to raise the depressed fragment. If this cannot be effected, a small incision should be made at the most advantageous point, avoiding making the fracture an open one. Through this incision access is gained directly to the bone. By means of a narrow periosteum elevator, retractor, hook, or a screw elevator the fragment can be raised into its normal position. Without making any small incision Codman has raised the depressed bone by grasping it securely with a double hook through the skin.

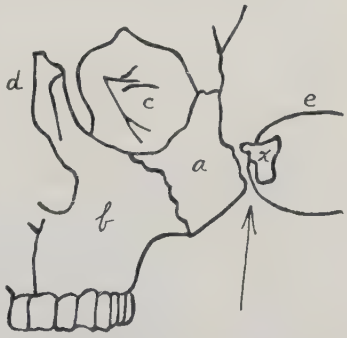


Fig. 51.—Fracture of the zygoma. A wire (*e*) threaded to a curved needle is passed under the fragment that is depressed (*x*). Traction on this wire will assist in elevation of the fragment. *a*, Malar; *b*, maxilla; *c*, orbit; *d*, nasal process; *e*, wire; *x*, zygoma and seat of fracture. The arrow points to the fracture (after Matas).

Union occurs in two weeks. There is no tendency to a recurrence of deformity, therefore no retentive apparatus is necessary.

The surgeon is not uncommonly asked to remove the slight depression attending a healed fracture of the malar bone. This may be most difficult. It should be attempted, however, as in fresh injuries, without a cutting operation, or by an incision within the mouth through the mucous membrane, or by an opening in the antrum and pressure outward with a blunt instrument (see next section), or, if necessary, by an external incision.

CHAPTER III

FRACTURES OF THE MAXILLA AND THE MANDIBLE

KURT H. THOMA, D. M. D.

ETIOLOGY: Predisposing causes, Exciting causes.

CLASSIFICATION.—EXAMINATION: History—Symptoms—Inspection—Roentgen examination—Complications.

PROGNOSIS.—TREATMENT: Emergency measures—Prophylactic treatment—Possible methods of fixation of fractures of the jaws—Method of fixation for fracture of the maxilla—Methods of fixation for fracture of the mandible anterior to the last existing molar: Interdental ligation, Oliver method, Intermaxillary ligation, Horseshoe wiring, Essig's method, Metal splints, Vulcanite rubber splints.—Method of fixation for fracture of the mandible posterior to the last existing molar: Intermaxillary splint with jack-screw, Goughlin's method—Method of fixation in fracture of edentulous maxillary or mandibular bones: Gunning splint, Direct wiring of the bone—Method of fixation for multiple fracture and combination of the three classes: Circumferential wiring, Kazanjian's method—Method of fixation for fracture complicated by loss of bone—Ununited and malunited fractures of the jaws.

OPERATIVE PROCEDURES FOR REDUCTION OF FRACTURES OF THE JAWS: Anesthesia: General, Local—Alignment of the fragments.

THE TREATMENT OF SEPTIC FRACTURES.—AFTER-CARE—HYGIENE OF THE MOUTH AND FEEDING.—AFTER-TREATMENT.

Of the upper and lower jaw bones, the mandible is more exposed to violence and is, therefore, more frequently fractured than the maxilla While the maxilla is an immovable bone, with no muscles tending to displace the fractured parts in fractures of the mandible, we have a movable bone to which many muscles are attached which play a part in the displacement of the fragments.

The importance of securing skilful treatment at once for fractures of the maxillary bones cannot be overemphasized. Malocclusion with ultimate loss of valuable teeth and deformities of the facial contour are more often than not caused by inadequate early treatment which generally consists in supporting the mandible by bandages. These bandages tend to displace the fragments, making subsequent reduction of the fracture extremely difficult.

ETIOLOGY

Pathological Fractures.—Rachitis and osteomalacia are rare general diseases which may predispose to fracture. Osteomalacia may cause a decalcification and softening of the teeth.[1]

Dentigerous cysts (Fig. 52), cystic odontomata, or peridental cysts formed from an abscess at the root of a tooth which contains epithelium often grow to tremendous size at the expense of the bone, and weaken the latter greatly.

[1] Loew, Deutsche med. Wochenschrift, Nr. 30, 1919.

Osteomyelitis often causes spontaneous fracture of the mandible. In a case of osteomyelitis of syphilitic origin the patient woke in the morning finding his "teeth would not fit together right." Carcinoma in the mandible will also

Fig. 52.—Dentigerous cyst and cystic odontoma side by side. Note how the bone of the mandible has been weakened and could easily be fractured.

destroy the bone to such an extent that the slightest amount of pressure will fracture it (Fig. 53).

Fractures Due to Trauma.—A blow on the jaw from various causes may be the cause of fracture. The extraction of an impacted mandibular third molar or other unerupted and malposed teeth may cause fracture of the

Fig. 53.—Carcinoma of the mandible. Notice loss of bone and spontaneous fracture, clearly visible at the inferior border. Part of the hyoid bone just in front of it.

mandible, either when the jaw becomes weakened on account of size and location of the extracted tooth, or, if misdirected, unusual force is applied to remove it.

CLASSIFICATION

Simple fractures of the maxillary bones are very rare. Depressed fractures are seen in connection with the thin anterior and external wall of the maxillary sinus. Compound fractures may be due to the involvement of the alveolar sockets of the teeth, the breaking of the skin of the face and mucous membrane covering the oral and nasal aspects of the bone. Injury of blood-vessels and of the inferior or superior alveolar, the palatal or the lingual and

infra-orbital nerves, and obliteration or compression of the lacrimal canal are complications which are met with.

In the mandible incomplete fractures are not very common, fissured fractures occur occasionally (Fig. 54). Multiple fractures of the mandible are just as often bilateral as they are unilateral. In all cases of fracture in the region of the mental foramen caused by direct violence one should always carefully examine the region of the angle of the mandible on the other side. In 5 cases out of 10 one will find a fracture at the angle of the mandible on the opposite side caused by indirect violence. Fractures are often comminuted and the cancellated bone may be crushed.

The Fracturing Force.—The degree and direction of the fracturing force, the obliquity of the plane of fracture, the muscle pull, and the degree of laceration of the soft parts all determine the displacement of the fracture

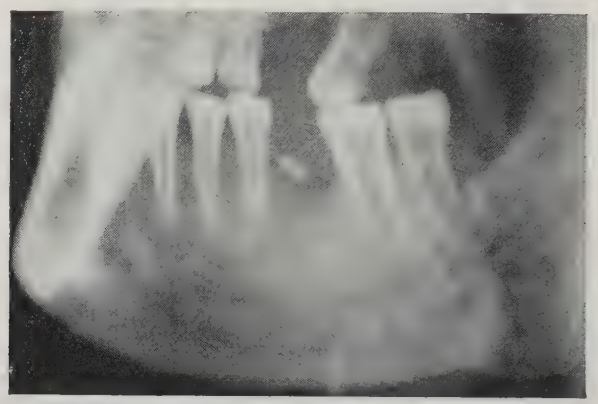


Fig. 54.—Roentgen picture showing fissure fracture below and distally to the last molar.

fragments of the jaw. A thorough knowledge of these factors forms the foundation for successful treatment.

The *most practical classification* of fractures of the jaws is that which relates to the method of treatment, as Kazanjian points out. Fractures may be grouped as follows:

Fractures of the maxilla.
Fractures of the mandible anterior to the last existing tooth.
Fractures of the mandible posterior to the last tooth.
Fractures of edentulous maxillary and mandibular bones.
Multiple fractures and combinations of the three classes.
Fractures complicated by loss of bone.
Ununited and malunited fractures.

EXAMINATION

History.—The history in all cases of injury will give very important information—the nature of the accident, the direction and manner in which the force was applied should be investigated. In pathological fractures the patient may remember hearing a snap or feeling a sudden sharp pain.

Symptoms of diagnostic value are often present and are so marked that a diagnosis is easily made. Loss of the power to masticate or to occlude the teeth properly and asymmetry of the facial outlines may be present with drooping of the corner of the mouth on the affected side. *Pain* may be referred to any part of the face on the affected side supplied by the fifth

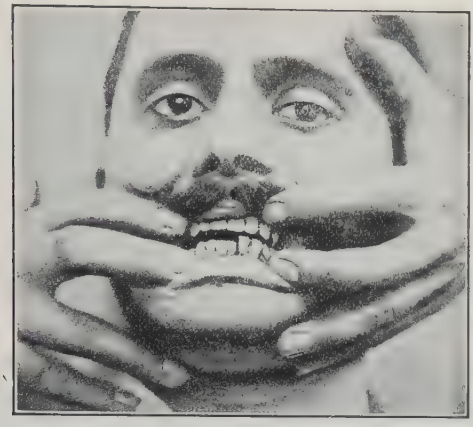


Fig. 55.—Fracture of lower jaw. Note the loss of alignment of the teeth of lower jaw.

nerve. *Localized pain* is generally only felt when the jaws are moved, and connected with this is often a grating sound caused by friction of the fractured parts; this may be audible to the patient only. *Numbness* is often complained of. The *paresthesia* is, of course, caused by injury of or pressure exerted upon a nerve and may be felt in the various parts supplied by the sensory branches of the fifth nerve. Paresthesia of the *upper lip* points toward fracture of the anterior part of the maxillary bone. Paresthesia of the *cheek* may be looked at as a symptom of fracture of the region of the zygomatic process. If the anterior or posterior part of the *palate* is affected, fracture of the alveolar process of the maxilla may be suspected. A numbness of the *lower lip* is caused by a fracture of the mandible on the respective side situated between the mental foramen and the mandibular foramen of the ramus.

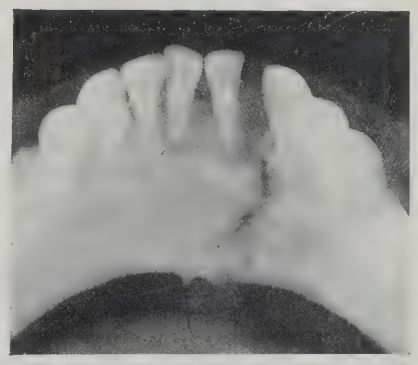


Fig. 56.—Roentgen picture of a fracture of the mandible in the anterior part between cuspid and central incisor. (Intra-oral film.)

Inspection of the occlusion of the teeth may or may not show the presence of a fracture (Fig. 55). If the fracture occurs posterior to the last molar the occlusion may be disturbed. Testing the motility of the jaw often leads to the diagnosis of a fracture. Gentle manipulation may disclose abnormal mobility in a place where there should be none, or there may be motion in

one portion of the bone while the other part is at rest. Laceration of the soft tissues of the oral cavity may be found. Hemorrhage at the point of fracture and excessive salivation may be present. In cases of longer duration edema and ecchymosis may occur.

Roentgen Examination.—It may be necessary to take intra- and extra-oral pictures and take exposures from different aspects (Fig. 56). In more complicated and obscure cases stereoscopic Roentgen pictures will be of value.

The Roentgen picture will show foreign bodies. The amount of displacement is distinctly visible, as is also the loss of bone substance. In multiple fractures it often discloses small fragments which would otherwise have escaped notice—these may be near their normal location or may have been carried away a considerable distance.

Infections connected with teeth situated near the fracture, and teeth which are extending into the line of fracture or which have been displaced will be detected (Fig. 57) by the Roentgen ray.

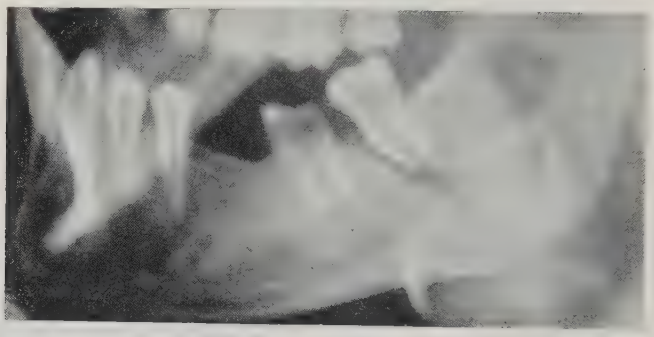


Fig. 57.—Roentgen-ray picture of a fracture of the mandible. The mesial root of the third molar extends between the fractured fragments.

In pathological fractures the nature and extent of the disease is at once recognized. We may find a large cyst, extensive ostitis or osteomyelitis, or we may find bone destruction caused by a malignant tumor.

It is not safe to draw final conclusions about the position of the fragments prior to fixation.

Periodic Roentgen-ray examination is of value to determine the result right after reduction and fixation of the fragments and to follow the process of healing.

COMPLICATIONS

Infection is often present in fractures of the jaw, and causes the formation of abscesses and cellulitis in the adjacent tissues. Infection of the bone at the site of the fracture may interfere with the process of repair and become the cause of the formation of sequestra with fistulæ. The fractured bone also becomes frequently infected from dental infections on nearby non-vital teeth or from teeth which have been injured during the accident, causing peridental abscess formation.

Hemorrhage, which may be considerable, is generally easily controlled by the application of pressure. Secondary hemorrhage occurs in cases where a great deal of mutilation has taken place, or in cases of extensive infection and sloughing of the soft tissue. Hemorrhage is liable to occur where foreign bodies are present.

False ankylosis may be present. This interferes with the opening of the jaw and is due to trismus of the muscles controlling the movement of the mandible. It is caused by injury of these muscles producing edema. Trismus of the muscles attached to the maxillary bones may also interfere greatly with attempts to manipulate the fragments into their proper position, making it necessary to administer ether for anesthesia to produce muscular relaxation and painless manipulation.

In certain traumatic cases injury of the mandibular joint may cause complications which are not always apparent until after union has taken place and the patient tries to move the jaw. Lyons states that immediately after the fracture there is often more or less abundant hemorrhage into the joint. There is an osteo-arthritis resulting in an osseous ankylosis.

In the maxilla the maxillary sinus may become infected and require special attention, and if the injury is associated with injury of the base of the skull cerebral symptoms may subsequently develop even though there may be no visible signs in the beginning. Coma and death may result.

PROGNOSIS

Age has an important influence on the process of healing. Local conditions play an important part—infection will retard, and an interposed tooth, foreign body, or sequestrum will often entirely prevent, osseous union. Cases in which proper treatment has been delayed will prolong the process of repair, especially if partial union with unsatisfactory alignment has taken place.

Simple fractures under favorable conditions will unite on an average of four weeks in the maxilla and six weeks in the mandible. Compound, comminuted, and complicated fractures will take considerably more time. If suppuration is present, corrective and retentive appliances cannot be safely removed for at least three weeks after the purulent discharge has completely stopped or the sinus has healed.

As to the result from an æsthetic point of view and from efficiency of mastication much depends upon the location of the fracture and the facilities which the case presents for efficient fixation. The best results are obtained in the cases of fracture anterior to the last existing tooth. In cases of fracture posterior to the last existing tooth perfect results are not so easily obtained. Fractures of the condyle, fortunately rare, generally result in permanent ankylosis.

A certain amount of stiffness and lessened function is always present when the appliance is first removed, but ordinarily this will disappear entirely, so that normal conditions are restored in from two to twelve weeks.

TREATMENT

The treatment is here arranged according to the applicability to individual cases.

In the treatment of fractures of the maxilla and mandible it is of greatest importance to endeavor to get as perfect an anatomical result as possible. Poor alignment will not only be disastrous from a cosmetic point of view, but will produce serious functional disturbances. Proper mastication is often greatly interfered with from a very small change in position of the fragments. In such cases after treatment it is often only possible to bring a few teeth in contact, the others remaining separated when the jaws are closed, a condition which is spoken of as an "open bite." Small discrepancies can be adjusted by grinding the teeth, while larger adjustments can be made by means of dental restorations, but many times the damage is irreparable, the motion of the jaws being associated with great discomfort and the malocclusion resulting ultimately in the loss of perfectly good teeth.

Fig. 58.—Barton bandage.

Fig. 59.—Four-tailed bandage for fractured jaw.

Emergency Measures.—Simple fixation should be the aim of first-aid measures. External wounds, if there are any, are, of course, taken care of first. The mouth should be inspected for the removal of broken off tooth fragments or very loose teeth that can be easily removed.

The patient should be asked to rinse the mouth thoroughly with a mild antiseptic solution, such as can be easily prepared by adding a teaspoonful of ordinary salt to a glass of warm water and pouring one-half a teaspoon

of tincture of iodin into it (1 pint of saline with 1 ounce of tincture of iodin). In most cases it will be sufficient to apply a Barton bandage (Fig. 58).

Dental modeling compound may be used. It is warmed in hot water until it becomes plastic. Roll it into sausage shape and place it over the entire dental edge of the normal jaw, pressing it over the sides of the teeth. Let the patient close his jaws while the fragments are pressed into their approximate position. Direct the patient to apply pressure with the tongue against the compound over the teeth inside the mouth. A four-tailed bandage will suffice for support of the mandible (Fig. 59). The use of modeling compound is especially applicable to edentulous cases.

It must be clearly understood that this treatment is only for intermediate use, while Roentgen pictures are taken and arrangements are made for permanent reduction and fixation. The chances for good results with bandages

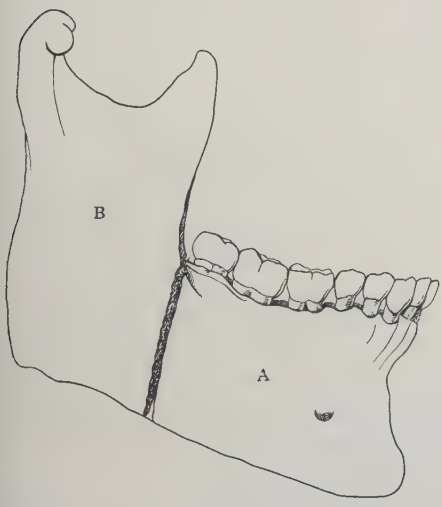


Fig. 60.—Direction of fracture is vertical to long axis of mandible.

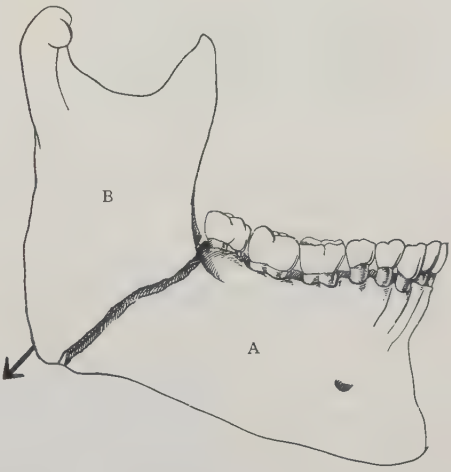


Fig. 61.—Fracture plane oblique running down and back. If segment A is fixed, B can still move in direction of arrow.

alone are very small in simple cases, and in more difficult cases the results are often worse than no treatment at all.

Prophylactic Treatment.—To diminish the probability of infection and disease of the oral tissues during the period of healing, when it is difficult to keep the teeth perfectly clean, the entire oral cavity should be put into as hygienic condition as circumstances will allow. Broken down roots and teeth with septic processes about them should be extracted; calcareous deposits on the teeth should be removed. This is also the time to take out teeth which are situated in the line of fracture.

Possible Methods of Fixation of Fractures of the Maxilla and Mandible.—There is no universal method which is applicable to all cases of fractures of the maxillary bones. It is necessary in each case to decide on a method which one thinks is most suitable. If splints are to be used, these must be

constructed before undertaking to reduce the fracture. It may be said in a general way that one should always choose the simplest method, the one which gives opportunity to observe the occlusion of the teeth during the

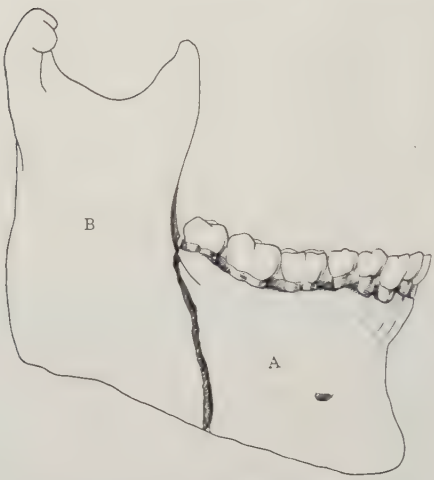


Fig. 62.—Fracture plane oblique running down and forward. If segment A is fixed, B will be prevented from moving up.

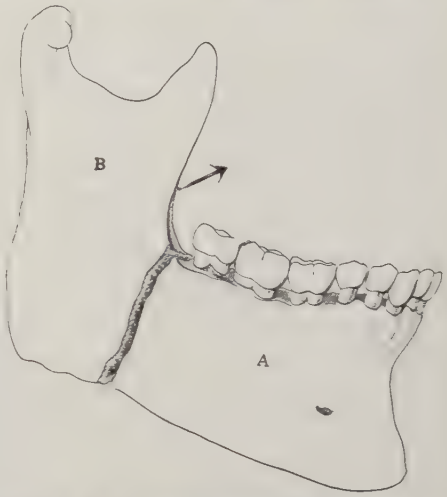


Fig. 63.—Fracture oblique backward from the internal to the external surface. If fragment A is fixed, a displacement of B is possible toward the inside.

process of healing, giving assurance that no accidental displacement occurs. It should be sanitary and lend itself to a simple method of cleaning.

The kind of fixation to be used must be chosen principally according to the amount and type of the original

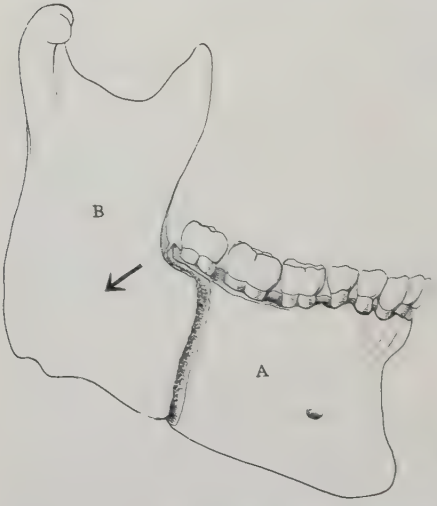


Fig. 64.—Fracture oblique backward from the external toward the internal surface. If fragment A is fixed a displacement of B may occur toward the outside.

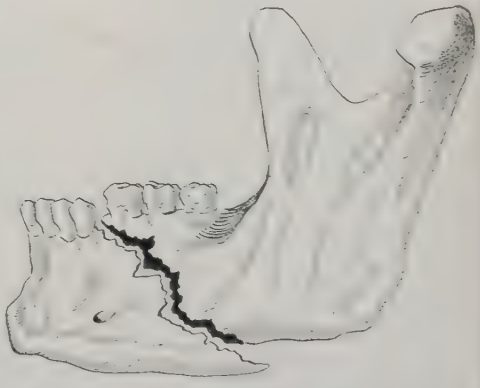


Fig. 65.—Fracture line permitting displacement of ramus in an upward direction.

displacement. The displacement of the fragments depends on two factors—direction of the fracture line and muscle strain.

Direction of Fracture Line.—The direction of the fracture surface may

either be vertical to the long axis of the bone (Fig. 60), oblique from above, either running down and back or down and forward (Figs. 61, 62), and oblique backward from the internal to the external surface of the bone, or else oblique forward from the internal to the external side (Figs. 63, 64). It is evident that in a case similar to the drawing (Fig. 62) fragment B will be held in place by fragment A, while in Fig. 61 there is no resistance to the displacement of fragment B in an upward direction (Fig. 65). If fragment A in Fig. 63 is fixed there is no resistance to an inward displacement, in the direction of the arrow of fragment B, while in Fig. 64 an outward displacement might be possible as indicated again by the arrow, but an inward displacement is resisted by fragment A. A Roentgen picture will often help to determine the direction of the fracture (Fig. 66).

Fig. 66.—Roentgen picture (intra-oral) disclosing an oblique fracture which on account of extensive overlapping remained unnoticed in an extra-oral plate.

Muscle Strain.—The immediate causes of the displacement are either the direct force of violence which caused the injury or the force due to muscle

Fig. 67.—Fracture of the mandible in the region of the mental foramen. Note obliquity of the fracture line. Note muscles contributing to the displacement of the fragments (after Davis and Peotti).

strain. Muscle strain, therefore, is a factor of magnitude and must be clearly understood because the method used for fixation of the fragments must coun-

teract this force (Fig. 67). In cases where the injury of the tissues surrounding the bone has produced inflammation of the soft part of the face, with a muscular trismus, the muscle strain is not only greatly augmented, but becomes an involuntary force of more or less permanent nature with a tendency to increase during the first few days.

In fractures of the *maxilla* there is generally very little displacement except in cases where the fracturing force is great. In horizontal fractures across the entire upper jaw, with injury of the mucous membrane, the slight pull from the buccinator muscle together with the force of gravity may have to be reckoned with.

In the *mandible* the muscle strain plays an important part. When the bone is intact the balance of the muscles is perfect, but when its unity is disturbed this balance is upset and the muscles which are not opposed will produce displacement.

The elevators of the mandible are the masseter, temporalis, and pterygoideus internus—they close the jaw. In case of fracture the first two will rotate the fragment inward and at the same time pull it up.

The external pterygoid pulls the jaw forward when the motion is bilateral and when it is unilateral produces the lateral motion, such as in mastication, the left muscle moving the jaw to the right and vice versa. In a fracture the muscle on the opposite side will cause a displacement of the larger part containing the incisor region toward the injured side (Fig. 72).

In a fracture below the head of the condyle the external pterygoid may or may not rotate the neck of the condyle forward. If the fracture line runs above, it will in all probability remain in its normal place. If the fracture line runs so that the muscle attachment remains connected with the fragment of the condyle, the neck of the condyle will be drawn forward and upward (Figs. 68, 69). The fragment made up of the larger part of the ramus will be pulled upward by the masseter and internal pterygoid as seen in the Roentgen picture (Fig. 96).

In a fracture of the coronoid process the action of the temporal muscle will cause the displacement of the smaller fragment.

The depressor muscles of the jaw are the mylohyoideus, the digastric, the genioglossus and the geniohyoideus, their attachments to the mandible are shown in Figs. 68 and 69 The mylohyoid muscles form the floor of the mouth, they run from the mylohyoid line to the median raphé (Fig. 70). They aid in deglutition and in case of fracture draw the smaller fragment inward (Fig. 71). In case of multiple fractures this muscle has an important influence on the lateral isolated fragments (Fig. 73).

The genioglossus and the geniohyoid muscles are attached to the mental spine situated in the median line at the inner surface of the mandible. They pull in a downward and backward direction. In case of a double fracture this will produce a downward or backward displacement of the fragment, or both, depending, of course, on the direction of the fracture surface (Figs. 74, 75). In case of single fracture a downward displacement will occur of the fragment to which the muscles are attached.

The digastric muscle is attached to the mandible in the digastric fossa, that is, a little to the side of the median line (Fig. 69). The direction of its force is the same as for the two muscles just described except that the place where it is attached is slightly lateral.

Under normal conditions the pull of the depressor muscles is neutralized by the elevator muscles, but when this control is interfered with, as it is in case of any fracture of the mandible, the muscles of the various groups will act separately and form new and different components, producing a definite displacement unless hindered by the position of the fracture surface of the opposing fragment.

The act of swallowing, coughing, talking, or unguarded movements of the head will, on account of the relation of the depressor muscles to the hyoid bone, cause derangement of the fragment often associated with pain.

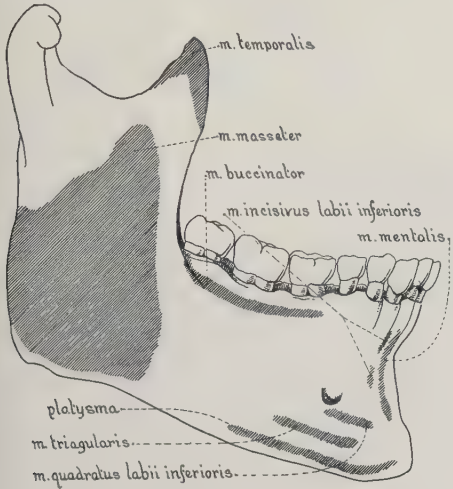


Fig. 68.—External surface of mandible showing muscle attachments.

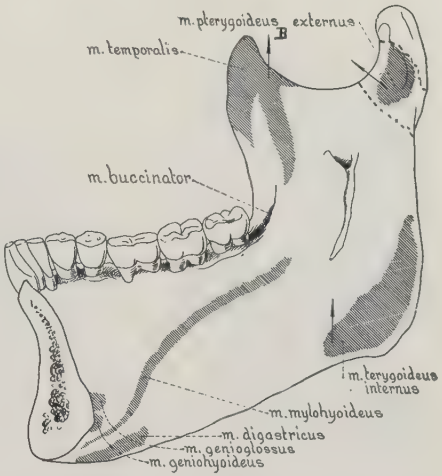


Fig. 69.—Internal surface of mandible showing muscle attachments. Arrow shows direction of force applied by external pterygoid, arrow B, by temporal muscle.

In case of double fracture near the symphysis of the mandible with free displacement of the fragment there is danger of the tongue falling back, causing dyspnea, even necessitating recourse to tracheotomy.

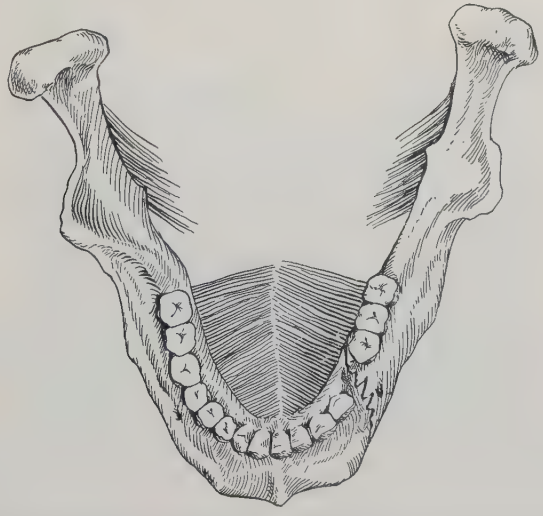


Fig. 70.—Note the plane of the fracture lies obliquely from inside outward and forward. Note that there is no muscular displacement under these conditions (after Davis and Peotti).

Method of Fixation for Fractures of the Maxilla.—The body of the maxilla is very delicate; its surfaces bound the maxillary sinus and are often the seat of depressed fractures. The orbital plate may be broken and the nasal process may be fractured, but the

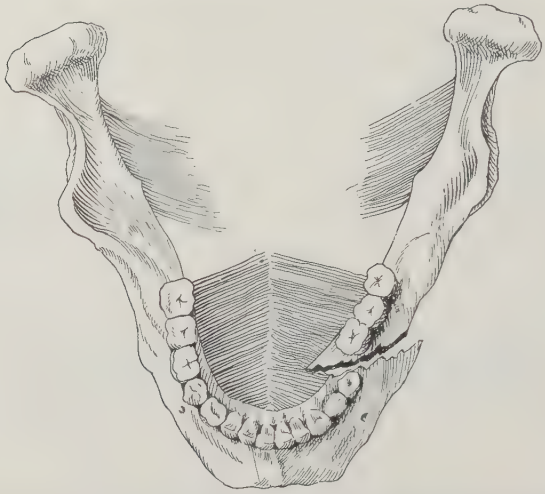


Fig. 71.—Oblique fracture of inferior maxilla. Plane of fracture from without forward and inward. Note the deformity due to the action of the internal pterygoid and mylohyoid muscles (after Davis and Peotti).

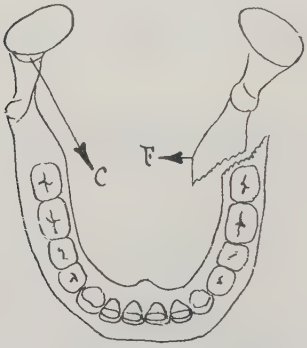


Fig. 72.—Muscle pull: *C*, Muscle pull by external pterygoid; *F*, displacement caused by temporal and masseter muscles.

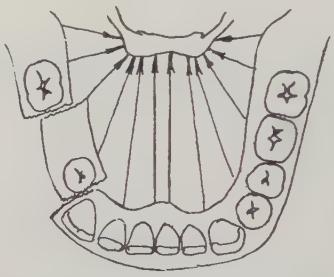


Fig. 73.—Action of the depressor muscles. In multiple fractures the mylohyoid muscle draws the isolated fragment inward.

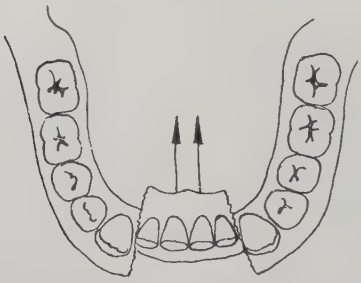


Fig. 74.—Backward displacement of isolated fragment due to genioglossus and geniohyoid muscles.

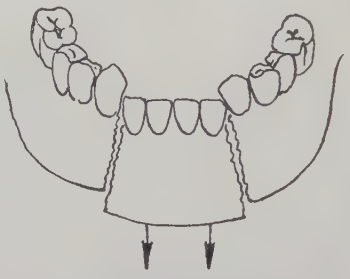


Fig. 75.—Downward displacement of isolated fragment due to genioglossus and geniohyoid muscles.

alveolar process is most frequently the seat of the trouble and the palatal process is often included. The injury very often involves the various contiguous bones. The nasal, the

palatal, the lacrimal, and the turbinate bones may be involved, and the malar bone may literally be depressed into the maxilla and remain impacted in its deforming position until removed. The course of the fracture is generally of an irregular nature and sometimes associated with emphysema and great swelling of the face. Hemorrhage may be considerable, but is easily controlled. The most frequent types of fractures of the maxilla are horizontal, partial or entire fractures of the alveolar process of the upper jaw, and depression fractures of the rest of the bone.

Depressed fractures of the maxillary bone require, as a rule, no mechanical devices for fixation; their treatment, therefore, will be dealt with in the paragraph on Reduction.

Fractures of the alveolar process which may extend into the rest of the bone require mechanical fixation.

If only part of the superior dental arch is included in the fracture, intermaxillary ligation, as described later for fractures of the mandible, gives the most satisfactory results, the sound opposing jaw forming a natural splint insuring correct occlusion of the teeth. If the loose fragment is larger than one-third of the dental arch additional support is needed. This can be secured by means of a Barton bandage (Fig. 58) or a chin cup attached to a head gear (Fig. 76).

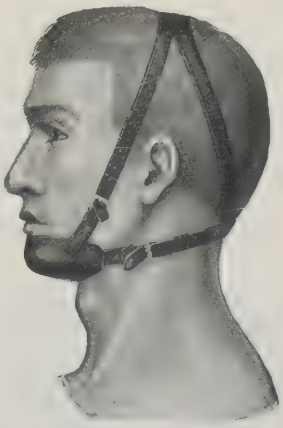


Fig. 76.—Molded leather chin-piece with buckles and straps for graduated pressure upon a fracture of the inferior maxilla (after Moriarty).

In cases which include injury to the nose associated with difficulty in nasal breathing, the patient must be able to breathe freely through the mouth. This makes it impossible sometimes to employ the above method. A so-called Marshall splint will be found of value. This splint is also applicable for horizontal fractures of the entire upper jaw.

Marshall Splint.—The splint is made in the following manner: Take an impression of the entire upper and lower arch in modeling compound. Pour plaster models and attach them to an articulator. It is necessary to cut the model of the upper jaw on the

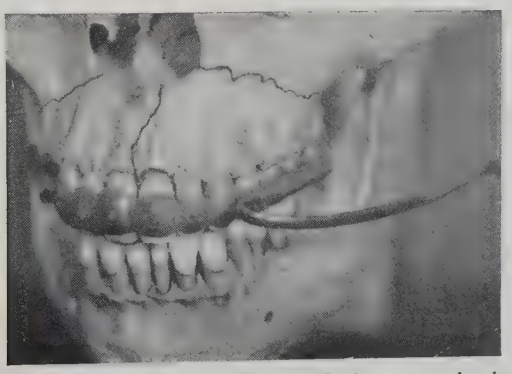


Fig. 77.—Marshall splint constructed by Harold J. Cutler. Elastic straps or bandages are used to attach the wire arms to a head gear.

place or places where the fracture has occurred and reassemble it to get the correct position of the fragments as judged by the occlusion of the teeth. From a die and counterdie swage a nickel silver-cap splint, and after trimming it to fit down over the teeth, but not further than the gum margin, reinforce it both on the inner and outer sides. Cut away the top part so as to expose the occlusial surfaces of the teeth and attach with solder two oval tubes to each side into which fit two heavy oval wires which can be bent later to con-

form to the outline of the face (Fig. 77). The splint is cemented to the teeth and fixation is secured by means of bandages which are attached to the wire arms and secured to a head gear. (The head gear can be made of padded metal bands and attached to the metal bars of the splint by means of elastic straps.) This splint allows motion of the lower jaw, but gives opportunity at all times to examine the correctness of the occlusion.

In a case of fracture of the upper jaw in an edentulous arch the artificial denture (rubber or metal plate) if it has not been damaged may be used as a splint. If it was broken, or if the patient's teeth had to be removed on account of the accident, a vulcanite splint in the form of a plate with or without teeth can be constructed on the corrected model as above. Oval tubes are attached and wire bars are bent and inserted and attached into each side.

Methods of Fixation of Fractures of the Mandible Anterior to the Last Existing Tooth.—In this group the teeth will not only be an aid in the adjustment of the fragments in their normal position, but they can also be utilized to retain the fragments until union has taken place. There are a number of good methods by which this intermaxillary fixation can be effected.

Fig. 78.—Instruments used for interdental ligation.

Indirect fixation by devices which hold the fragments together in their proper relation by pressing the lower jaw against the upper in correct occlusion are very unsatisfactory and should not be used. Barton, four-tail, or other bandages or head gear with chin-cup are useful as accessory supports and as first-aid measures.

Interdental Ligation.—This method is applicable to all fractures of the mandible anterior to the last existing tooth, fractures of the maxilla which include the dental arch, and fractures posterior to the last existing tooth in combination with other devices. The method can only be used if a sufficient number of sound teeth are present. Its principal advantage is the fact that it gives positive assurance of correct occlusion of the teeth; any change taking place through slight displacement during the process of healing will at once be noticed and can easily be remedied.

Metal splints which cover the teeth entirely or in part give opportunity for slight changes in the relation of the cusps of the teeth to their fascets, which will result in malocclusion which even when slight is extremely uncomfortable and requires a great deal of careful grinding of some teeth and building up of others with fillings, inlays, etc., to adjust the damage.

The advantage of interdental wiring is the simplicity of the method; it requires but few instruments and not as much expense as to time and material as the construction of an intermaxillary splint.

Disadvantages of interdental ligation are difficulties arising when vomiting. The method, however, allows reduction of the fracture without the use of general anesthesia in most cases. (See Anesthesia.) Any other causes of nausea and vomiting, such as sea voyages, must be avoided, and it should be made a practice to have wire scissors in readiness at all times, with which the wires can be cut apart, especially in hospital patients. Breathing through the mouth is made more difficult in this method, therefore it is contraindicated when the nasal passages are obstructed. Eating, that is, mastication, is impossible. Even where there are no missing teeth to facilitate feeding, the patient can take enough liquid food so as to even gain weight. Strict hygienic measures are necessary to keep the mouth and teeth as clean as possible.

Simple Interdental Wiring.—The Gilmer method used today consists of direct wiring of the upper teeth to the lower ones so as to insure correct

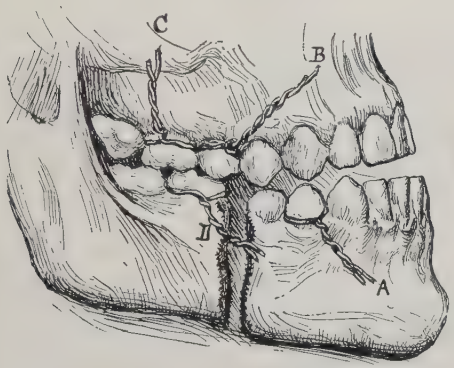


Fig. 79.—Fracture of lower jaw. Note the wires *A*, *B*, *C*, *D*, placed about certain teeth just before they are joined and the fracture is reduced (George Wright).

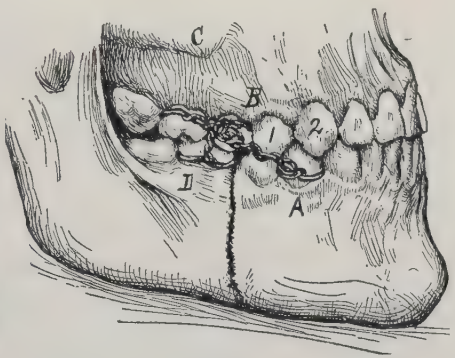


Fig. 80.—All wires have been twisted until the fracture has been reduced. Note the index of the normal occlusion of the teeth of upper and lower jaw—1, 2, *A* (George Wright).

occlusion. If the fragments are adjusted so that the teeth come together normally the fractured bone cannot be materially displaced.

The wire that may be used for this purpose is No. 24 soft iron wire such as is employed by florists and which can be obtained in hardware shops. Other suitable wire is annealed copper wire 22 G. or brass wire 24 G. Angle brass ligature wire may be used for this purpose. For the application of these ligatures four teeth should be selected for the wiring on each side of the jaw. One of the wires should be placed at least one tooth distant from the line of fracture. Choosing a tooth somewhat distant avoids the tendency to loosen the teeth in the immediate proximity of the fracture (Fig. 79). The teeth selected should be wired singly first before proceeding to approximate the fragments.

The wires, about 45 cm. long, should be bent in the middle to the shape of a hairpin and passed from the inside between the interdental spaces near the gum margin on each side of the chosen tooth. The two free ends of the wire will project then out of the mouth after encircling the tooth. These two ends should be twisted gently together in a move-

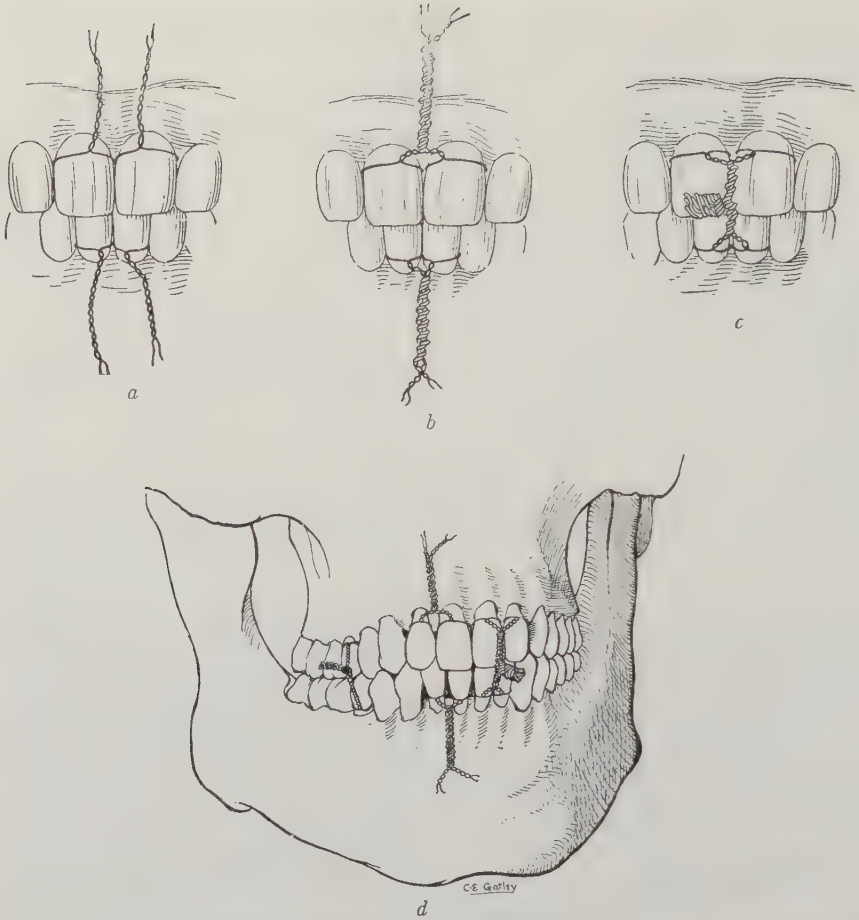


Fig. 81.—*a*, *b*, *c*, *d*, Methods of placing and completing the wiring of the teeth contiguous to a fracture of the jaw (after Kazanjian).

Fig. 82.

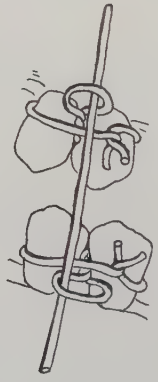


Fig. 83.

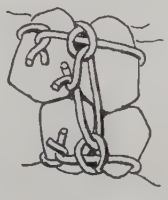


Fig. 84.

Figs. 82–84.—Oliver's method of interdental ligation.

ment to the right, as in the direction of the moving hands of a clock. All twisting of wires singly or together should be done in the same direction to avoid untwisting. Wires should be twisted as tightly as possible around the individual teeth. Now bring the wires from the upper and lower teeth together in pairs, but diagonally, with gentle but firm pressure. During this preliminary wiring the fractured fragments are brought into apposition and the teeth are brought approximately into their alignment. A very accurate measure of the precision of alignment will be found in the recognition of the fact that the canine tooth of the lower jaw (that is, the lower cuspid) should occupy the space between and beneath the lingual surfaces of the upper cuspid and adjacent lateral incisor. (See Fig. 80 and note that *A* rests between 1 and 2.)

Finally, all wires should be tightly twisted. After cutting off the projecting surplus of wire the ends may be rounded free from sharp points, and turned inward toward the teeth to avoid cutting the cheeks and lips. It may be at times necessary to protect the soft parts by applying with wet fingers a small piece of heated gutta-percha over the ends of the wires.

A variation of this method is that employed by Dr. Kazanjian. He unites the wires of two adjoining teeth on the incisors, that is, he wires these teeth in pairs, while in the posterior part of the mouth he unites single opposing teeth (Fig. 81, *a*, *b*, *c*, *d*).

Oliver Method.—Wire 6 inches long, as above, 24 G. on posterior teeth, 22 G. on anterior teeth, is bent in the middle and twisted around an instrument to form an eyelet (Fig. 82). After selecting the teeth to be wired both ends of the eyelet wire are inserted from the outside through the interdental space. One end is drawn around the anterior tooth, the other is drawn around the posterior tooth, then the ends are twisted together (Fig. 83). In the upper jaw the eyelets should project above, in the lower jaw below, the horizontal twist, which prevents them from coming too close together. While twisting the wire a towel clamp may be inserted into the eyelet to prevent it from disappearing into the interdental space. The ends are cut off and must be bent so as not to irritate the lip or cheek. Two or three sets of teeth are prepared in this manner on each side of the jaw and the opposing eyelets are finally connected by passing a third wire through them twisting it to draw the teeth together (Fig. 84). On the fractured side the location of the upper and lower eyelets should be selected so as to draw the fragments together, that is, instead of having the opposing eyelets in a vertical line they should be arranged obliquely, the eyelet in the fractured jaw being further away from the fracture line than in the uninjured jaw.

The advantage of this method lies in the fact that the wires are not so liable to break, and if one should break, it can be replaced without disturbing the other eyelet. If it is necessary to open the patient's mouth, this can be done by cutting the third wires, which, as is evident, are very easily replaced. The method, therefore, gives also opportunity to test the union of the fracture, and if consolidation is not complete the interdental ligation is easily re-established.

Silverman Method.—A variation of the Oliver method, but using the ends of the wires directly, twisting them together with the ones of the opposing teeth. After passing the wires around the two adjoining teeth they are passed through the loop, forming a slip-knot, giving a firm attachment to the teeth without tightening around the neck of the tooth by twisting (Figs. 85, 86). While this prevents one source of breakage it does not modify the other disadvantages of Gilmer's method.

Intermaxillary Ligation.—Other methods have been devised to facilitate the fastening of the upper to the lower jaw. Small bands have been made

Fig. 85.—Silverman's method of interdental ligation. (See Fig. 86.)

Fig. 86.—Silverman's method. (See Fig. 85.)

Fig. 87.—Wire splint constructed after the method of Harold J. Cutler.

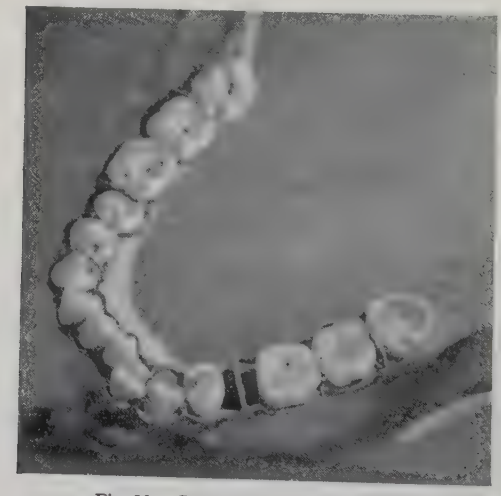


Fig. 88.—Cutler splint. (See Fig. 87.)

which can be fastened around individual teeth, having knobs or spurs attached, to which a wire ligature can be fastened.

Wire Splint.—A wire splint of both dental arches gives opportunity for easy and effective intermaxillary ligation. While the wire can be fitted directly in the mouth, better results are obtained by taking an impression and making models of both the upper and lower teeth.

An 18 G. wire is bent to fit around the outside and inside of the teeth near the gum margin and soldered to be continuous around the entire arch of both the upper and lower jaws. These wires are placed in the mouth and fastened either by wiring to each individual tooth, or by passing secondary wires from the inner bar to the outer bar through the interdental space. This is generally sufficient to prevent it from moving up (Figs. 87, 88).

Essig Method.—In favorable cases this method may be used without intermaxillary ligation, but not without supplementary indirect fixation by means of efficient bandages.

Fig. 89.—Essig's application of wire splint.

Two thicknesses of 30 G. wire are used. Start four teeth or more away from the fracture and lace the wire around the necks of the teeth (Fig. 89) until you reach the second tooth from the fracture. Stretch the wires to the second tooth on the other side of the fracture and then lace it around two or more teeth again. This places the ligature straight across over the external surface of four teeth nearest the fracture and on the inside it spans across the curvature of the arch. After this wire has been placed and fastened secondary wires are placed as in the illustration between the teeth, and these are twisted so that the shortening of them will bring the inner wires to the inner surface of the teeth. This is done with the patient closing the teeth together so as to assure normal occlusion. It is easily seen how efficient this process is in drawing the broken parts together. If teeth are lost in the region of the fracture, a piece of vulcanite can be made from a wax pattern to be inserted in the space. Intermaxillary ligation may be used in addition.

Metal Splints.—These are used in fractures of the upper jaw, as already described. In the lower jaw they are also at times used for simple fractures anterior to the last existing molar, their advocates pointing out that with them it is possible to secure sufficient fixation without interdental ligation.

The use of the metal splint should be reserved for difficult cases if there are not sufficient teeth for interdental ligation, or if the teeth are not strong enough, as deciduous teeth in children or pyorrhea teeth in adults. It is especially useful as a basis for more complicated appliances in some of the classes of fractures to be described later.

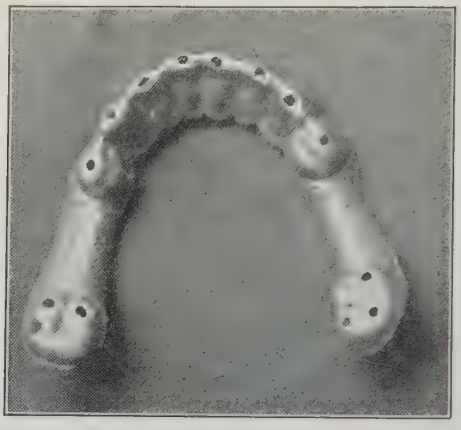


Fig. 90.—Aluminum splint to be placed on teeth. For closed fracture a continuous capping of gold or aluminum or other metal cemented upon the teeth.

The Construction of the Metal Splint.—Take impressions of both the upper and lower jaws in modeling compound softened in hot water. Models are made from these impressions in plaster of Paris. The model of the lower fractured jaw is cut apart in the exact location of the fracture and reassembled on an articulator to meet the upper teeth

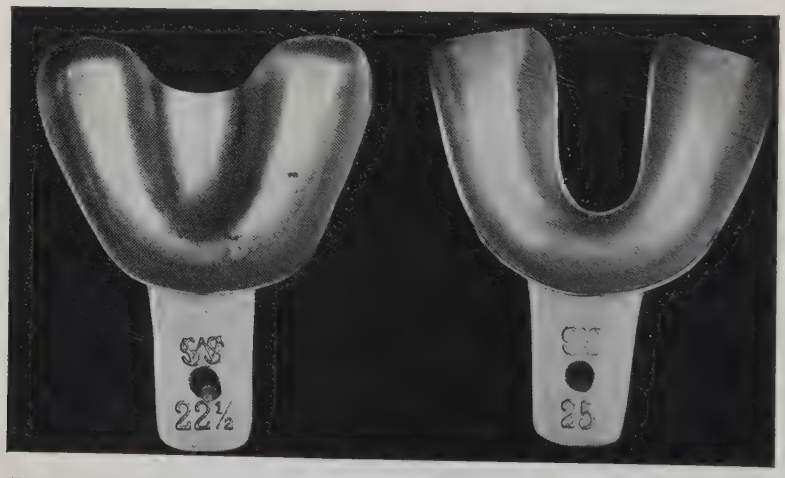


Fig. 91.—Modeling cups. No. 22½ is used for the upper jaw and No. 25 for the lower jaw.

in normal occlusion. A piece of metal, gage 32, silver aluminum, German silver or 18 karat gold may now be swaged over a metal die made from the model of the lower jaw. A casting can be made instead from a wax pattern constructed on the model. For reinforcement solder 18 G. wire along the border of the splint, or reinforce the entire sur-

face. The occlusal surface is cut away entirely, which gives opportunity to observe the occlusion more correctly, when in place. Otherwise, holes must be made in the oc-

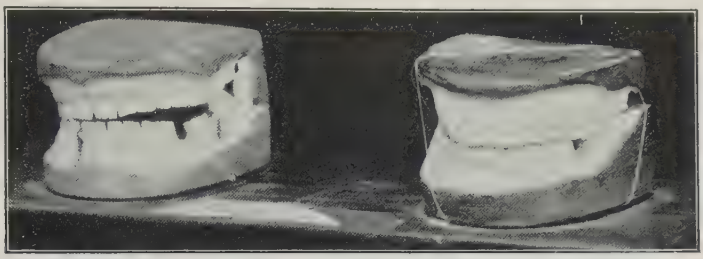


Fig. 92. Fig. 93.

Fig. 92.—Plaster cast of fracture of the jaw.
Fig. 93.—Plaster cast of lower jaw articulating with upper jaw.

Fig. 94.—Simple vulcanite splint, with boxes vulcanized on each side (Moriarty).

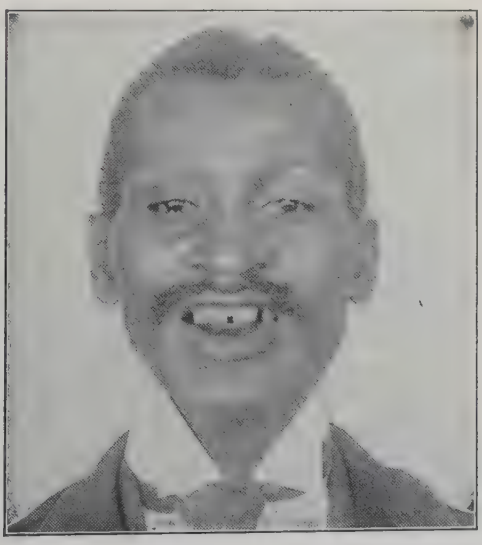


Fig. 95.—Hard-rubber splint in position, upper teeth resting upon it (Moriarty).

clusal surfaces of the splint (Fig. 90). Dry the metal and the teeth (applying alcohol and air by pressure) and keep the saliva away by the use of cotton rolls or gauze; fill the splint

with thinly mixed dental cement and press it over the teeth in its proper place. The surplus cement will come out through the holes in the top of the splint. Sometimes small holes are made in the side of the splint corresponding with interdental spaces. These serve to further fixation by means of wires. These are drawn through the holes on the inside of the splint, passing through the interdental space on each side of a tooth out through holes on the external side of the splint, where they are twisted together, cut off, and bent over.

Vulcanite Rubber Splints.—All that has been said about metal splints is applicable to vulcanite splints. They are made as follows:

An impression is again made of the crowns of the teeth and the adjoining gum in modeling composition manufactured for the use of dentists. The necessary amount of the composition is dropped into hot water; when soft, the composition is put into the metal impression cups (Fig. 91). Then the impression cup containing the softened composition is placed in the mouth and the impression made. Immediately upon the removal of the mold from the mouth the composition cools and hardens. From this mold is made the duplicate of the alveolar border and the teeth in plaster of Paris (Fig. 92). The lines of fracture are indicated upon the plaster cast. With a fine saw the cast is cut upon these lines and the lower teeth are articulated with the plaster cast of the upper jaw which has been made. Plaster cream is used to hold the sawed portions together. In other words, the fracture has been reproduced and reduced in plaster of Paris. Both upper and lower casts are then put upon an articulator (Fig. 93). A vulcanite splint is made from this reconstructed lower jaw (Fig. 94), and when this is applied to the fractured jaw as an interdental splint the deformity is corrected and comfortably prevented from recurring. Holes may be made into the sides of the splint to draw wires through the interdental spaces for fixation. A rubber splint in place is shown in Fig. 95. Indirect fixation by bandages must be used in addition to this splint.

Method of Fixation of Fractures of the Mandible Posterior to the Last Existing Molar.—Much greater difficulties are presented in the fractures outside of the dental arch. The most frequent seat of this type of fracture is in the neighborhood of the angle of the jaw. Horizontal fractures of the ramus are very uncommon and fractures of the coronoid process are rare. A fracture which occurs from a boxing accident is the fracture of the condyloid process which usually occurs at the neck of the condyle.

In fractures near the angle of the jaw the method of procedure depends a great deal upon the direction of the fracture surface. If it extends from above down and forward, as in Fig. 62, the upward displacement of the ramus by the pull of the elevator muscles is stopped by the inclined plane of the fracture surface. If the fracture is properly adjusted, which is accomplished by pressing the ramus down and back while the anterior fragment is fixed by intermaxillary ligation, the distal fragment will remain in position naturally, the anterior fragment being fixed by means of interdental ligation or any of the methods described for the previous class.

Intermaxillary Splint with Jack-screw.—In fractures near the angle of the jaw, when the inclined fracture plane is oblique, running down and back as in Fig. 61, or if the fracture surface is also oblique from the inside toward the outside, as in Figs. 63 and 64, it is necessary to use a device which will

prevent an upward displacement, or an out and inward displacement of the ramus. (See Fig. 96.)

This is accomplished if a metal or vulcanite splint is used to fix the anterior fragment by the attachment of a jack-screw to the side of the splint of the upper jaw. The jack-screw bears down upon the ramus in the region of the postmolar triangle preventing lateral

Fig. 96.—Roentgen picture of fracture at the ramus. An attempt had been made to reduce this fracture by interdental ligation which was not successful, as is evidenced by the upward displacement of the ramus.

displacement as well as upward motion. As soon as the upper splint is in place the ramus can be controlled by winding or unwinding the screw. The part which is in contact with the ramus is in some cases a small saddle-vulcanite or metal splint, made after a wax model fashioned in the mouth, such as recommended by Blair, Eby, Herpin, and others. The writer prefers a jack-screw with a point as described by Blair, or a point with a side extension to prevent lateral motion. The motion of the jack-screw in these appliances bears

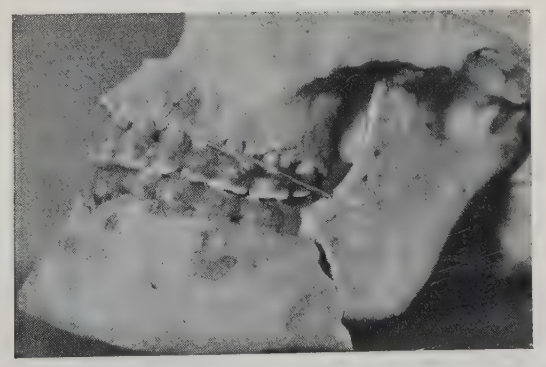


Fig. 97.—Intermaxillary metal splints with jack-screw for fixation of ramus. (Constructed by Harold J. Cutler.)

directly on the bone (Fig. 97). A small vertical incision is made under aseptic precautions in the postmolar fossa, exposing the external oblique line, and with a bone drill a small hole is made into the thick cortical bone of this region. The point made of silver or gold fits into this hole and controls its movements without the danger which always exists with the saddle-splint that inflammation of the mucous membrane and periosteum will occur, and also tissue necrosis caused by pressure on so large an area (Fig. 98). After the jack-screw is adjusted to press the ramus back the anterior fragment is brought into position and fixed by intermaxillary ligation, after which the final adjustment with the screw is made.

It may be necessary to use a Roentgen picture as a guide to insure correct position of the ramus.

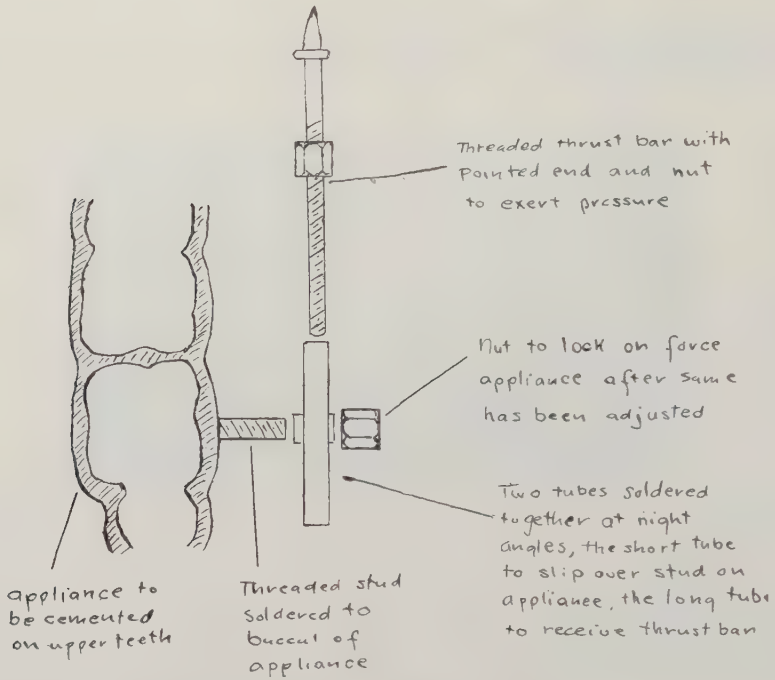

Threaded thrust bar with pointed end and nut to exert pressure
Nut to lock on force appliance after same has been adjusted
Two tubes soldered together at right angles, the short tube to slip over stud on appliance, the long tube to receive thrust bar
appliance to be cemented on upper teeth
Threaded stud soldered to buccal of appliance

Fig. 98.—Schematic drawing of jack-screw shown in Fig. 97.

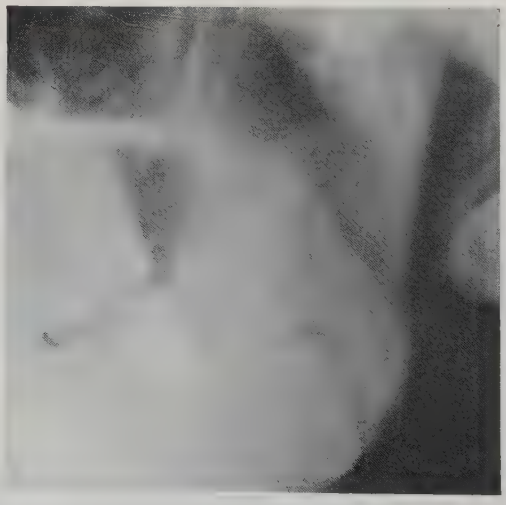


Fig. 99.—Roentgen picture of a fracture at the neck of the condyle. Note that the ramus has been displaced in an upward direction.

Horizontal fractures of the ramus can often be treated by means of intermaxillary splint with jack-screw. Direct suturing of the bone with silver

wire may have to be resorted to in some cases. The method because it leaves a scar on the face is not desirable except as a last resort.

Fractures at the coronoid and condyloid processes (Fig. 99) may also be treated by immobilization of the jaws as in the preceding instance or by open operation. The displacement in this type of fracture is often quite extreme. If it is due to the pulling forward of the jaw due to the action of the external pterygoid muscle (Fig. 100), intermaxillary fixation will very often reduce the displacement. If, however, the temporal muscle displaces the coronoid process, or if the external pterygoid muscle remains attached to the part containing the head of the condyle, this method will produce at best unsatisfactory results. If the neck of the condyle is pulled forward a fairly satisfactory but not perfect result may be obtained by drawing the lower jaw forward and fixing it in this position by interdental ligation until union

Fig. 100.—Fracture of the condylar process of the lower jaw. Note the displacement of the jaw forward.

has taken place. The coronoid process may have to be removed if treatment is unsuccessful.

Goughlin's Method of Fixation.—This method is applicable to cases of horizontal fractures of the ramus above the angle of the jaw, and is used when fixation with intermaxillary splints and jack-screw is not possible, and in place of the open operation with wiring or plating. While the latter is an operation of magnitude, Goughlin's method is comparatively simple, requiring only a small incision, and the danger of severing a branch of the facial nerve is minimized. It can be performed under a local anesthetic.

The incision is made parallel with the branches of the facial nerve, which go to the frontalis and upper half of the orbicularis palpebrarum muscles. The upper quarter overlies the zygoma, the remainder of it reaches from $\frac{1}{2}$ to $\frac{3}{4}$ inch below it. It should be not more than 1 inch in length and should extend only through the skin. This incision must be directly over the coronoid process; if one is not sure of the exact location of the coronoid process, the depth and position can be sounded for with a needle. After the incision is made a probe is passed close to the zygoma, down through the masseteric fascia

and the masseter muscle until the coronoid is felt. Closed, pointed scissors with long strong handles are passed alongside this probe until the point rests against the coronoid. The probe is withdrawn and, pressing the points of the closed scissors firmly against the bone, the scissors are opened, splitting the fibers of the masseter from the zygomatic border downward for an inch. Two small strong retractors are passed into the slit, and holding

Fig. 101.—Interdental splint used in fracture of the jaw when no teeth exist in upper alveolar arch (after Moriarty).

their ends firmly against the coronoid, retraction of the split masseter is made and the scissors are withdrawn. An assistant passes his finger into the mouth and reduces the fragments; while he holds them in position the operator drills a hole through the coronoid as close to the edge of the zygoma as possible. An ordinary wire nail, tin-plated, or a specially made silver nail, $1\frac{1}{2}$ inches long, is now passed through this hole until its flat head

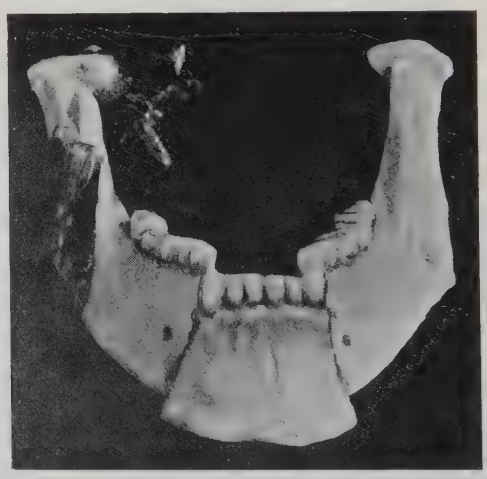


Fig. 102.—Double fracture of lower jaw (after Dorrance).

impinges upon the zygoma. If its head is turned up very slightly the point soon comes in contact with the under surface of the skull and it may not go far enough. When it is properly passed it effectively prevents the coronoid from rising as the nail catches on one end under the zygoma and its point comes in contact with the base of the skull. The wound is closed with figure-of-8 silkworm-gut through the masseteric edges and overlying struc-

tures. These control any oozing and there is no need of burying either ligature or suture material.

After this operation is performed the jaws are immobilized by any of the described methods. The nail is removed after four weeks and comes away easily.

Method of Fixation in Fractures of Edentulous Maxillary or Mandibular Bones.—It is evident that interdental ligation and intermaxillary fixation as described is not applicable to edentulous jaws, nor can these methods be used when the number of teeth is very small or if the teeth present are very loose. In small children when the permanent teeth have not yet erupted, and the deciduous teeth are decayed or loose, other methods must be employed. The construction of splints for such cases is along the line of vulcanite splints used for dentulous mouths.

Gunning Splint.—After plaster-of-Paris models have been made of the jaws and are corrected and articulated, a splint is made by modeling wax over the alveolar process of both the upper and lower jaws.

These two wax plates are then built up with wax to the height of the teeth in a normal mouth. They are removed from the model and placed in the patient's mouth to get the normal relation to each other. It is best to fuse them together right in the mouth with a hot instrument, when the mandible and its joints are in a comfortable position. The articulator is now adjusted so as to fit the models of the upper and lower jaws into their respective places in the wax. One or three places are cut out, these form openings through which nourishment can be taken. Such a splint, spoken of as a "Gunning splint," is shown in Fig. 101.

These splints will not in all cases secure absolutely accurate fixation; they must be used in conjunction with bandages or, better, chin-cup and elastic bandages connected to a head gear. Metal splints of this kind are preferable because they are more sanitary.

If the patient has artificial dentures and these have not been broken by the accident, the upper and lower can be fixed together with wires and the two will improvise a good splint for edentulous cases, especially if the front teeth are removed to make space for feeding.

Direct Wiring of the Bone.—In edentulous mouths, in both the upper and lower jaws, direct wiring of the bone may be resorted to. In the maxilla, if there is great displacement, the alveolar process may be attached by this method to the body. The fractured mandible in edentulous condition can often be treated by the same method with an intra-oral operation, but if the fracture is in the neighborhood of the angle of the ramus an extra-oral operation is required. Extra-oral operation, however, should not be used by choice on account of the great danger of dividing branches of the facial nerve, especially the inframandibular branch, and because it leaves a visible scar.

Intra-oral Operation.—If operating intra-orally an incision is made on the outer side of the mandible about 4 cm. long and at the lowest part of the sulcus. If near the mental foramen, care should be taken not to injure the mental nerve which supplies sensation to the lower lip and chin.

The bone must be reached about halfway between the inferior and superior border, 2 cm. each side from the fracture. Insert a sponge into the wound and make a second incision on the inner surface. Here the lingual nerve is avoided by keeping as close to the bone as possible. In the median line care must be taken not to cut the attachment of the geniohyoid muscle. Stop the bleeding with adrenalin, and if necessary use retractors in both incisions, which also protect the soft tissue, and with a bone drill make one or two holes in each fragment. If two are made, the wiring is done in criss-cross fashion. If only one hole is made on each side the placement should be so that the suture will cross the fracture line in a vertical direction; 18 or 20 G. pure silver wire or kangaroo-tendon can be used, but chromatized catgut should be tied over the knot to prevent slipping. The wires are left in position for from five to six weeks.

Method of Fixation of Multiple Fractures—Combinations of the Three Classes.—Multiple fractures anterior to the last existing molar (Fig. 102) can generally be treated with intermaxillary splints by methods already described. Unusual muscle pull sometimes must be overcome on the segment or segments between the proximal fracture lines. This can be accomplished by means of levers attached to the splint and acted upon by means of rubber bands or fixation to the opposite jaw, or to the head gear.

Multiple fractures anterior and posterior to the last existing molar are treated by intermaxillary fixation and jack-screw attachment.

Multiple fractures in edentulous cases can either be wired or plated by intra-oral methods or treated by circumferential wiring, a much better method, originally employed by G. V. Black and described by Ivy.

Circumferential Wiring.—Ivy describes this method as follows:

> A vulcanite splint is first made like a saddle to cover the lower ridge on each side of the fracture. Or if the patient has a full vulcanite denture, this may serve the purpose of a splint. A small incision is made in the skin at the lower border of one of the fragments and a small curved antrum trocar and cannula are passed up through this incision close to the bone on the lingual side, until the mucous membrane on the mouth is pierced. The trocar is then removed and one end of a 16 or 18 G. silver wire is threaded through the cannula from below. While the wire is held in place the cannula is withdrawn and by means of the trocar passed downward from the mouth close to the bone, this time on the external side, to emerge at the original skin opening. The other end of the wire is then passed up through the cannula and the cannula is withdrawn. One or more wires are then similarly passed around the other fragment or fragments, and after the splint is put in place the ends of the wires are twisted together, so that the bone is snugly in contact with the splint (Figs. 103, 104).

Comminuted Fractures.—If the jaw is broken into numerous small pieces which may contain no teeth the application of the usual method of fixation will be impossible. The fragments, in addition, may be displaced from 1 to 3 inches from their normal position and the fixation of the fragments is also resisted by the action of the depressor muscles.

Kazanjian Method.—A combination of maxillary splints, sutures through the bone, and extra-oral appliances should be used. Kazanjian states that

the first step is the construction of a splint which holds the proximal parts (the rami) in position.

If teeth are present, bands or metal crowns are constructed for them, and these are connected by heavy threaded arch wire (German silver 12 G.). It is cemented into place and will keep the posterior segments firmly in occlusion. If the teeth are absent

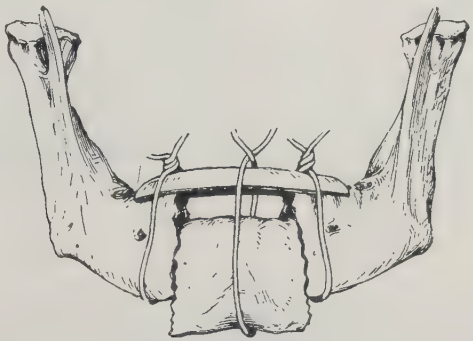


Fig. 103.—Circumferential wiring in bilateral fracture (Ivy).

on one side or on both the arch wire is attached to the side without teeth by means of a hole made through the anterior part of the ramus. The arch wire should follow the mandibular curve at about the normal crest of the bone. Wire sutures (Fig. 107) are passed through the anterior bony fragments and attached to the arch. They lift them into their natural position and contact. Horizontal fragments at the lower border of the jaw are in the same manner fixed into their place (Figs. 105, 106). A removable vulcanite splint has to be used in most cases in connection with these appliances to preserve the contour of the jaw. (See Fig. 107, which illustrates one of Major Kazanjian's cases.)

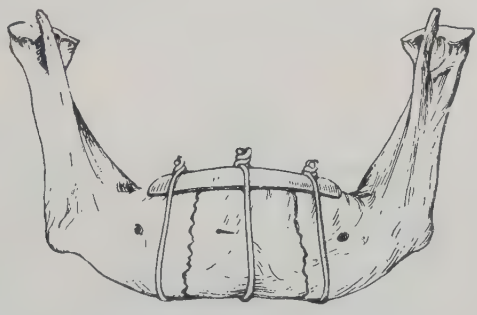


Fig. 104.—Circumferential wiring in bilateral fracture (Ivy). (See Fig. 103.)

Method of Fixation of Fractures Complicated by Loss of Bone.—Loss of bone is of no serious consequence as long as there is some contact when the fragments are aligned (Fig. 108). Even in badly comminuted fractures union will take place if there are a sufficient number of small pieces of bone with adequate blood-supply left to fill in the spaces. The weak places, however, must be protected until sufficient bone has filled in around them (Fig. 109) or the jaw is liable to refracture. In constructing a splint for such a case the space between the teeth where the bone is missing is kept open by connecting

the two parts of the splint with strong metal bars, which are attached with solder.

If the loss of bone is complete in a vertical direction, but only of small extent and in the molar region ($\frac{1}{2}$ to 1 cm.), the posterior fragment may be

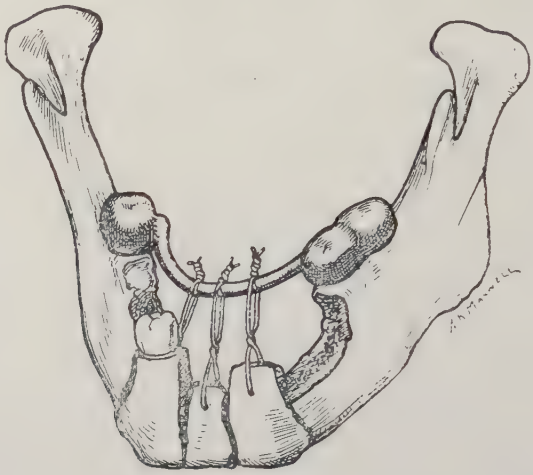


Fig. 105.—Apparatus constructed for comminuted fracture with teeth present in the proximal parts. (Courtesy of Major Kazanjian.)

drawn forward sufficiently to make contact, holding the anterior fragment in occlusion by means of intermaxillary fixation. To do this it may be necessary to grind the teeth in the posterior fragment.

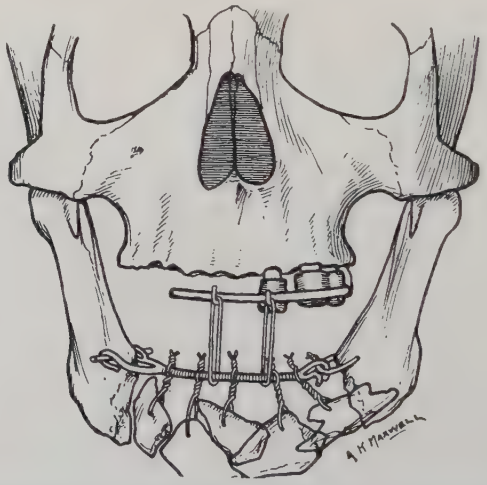


Fig. 106.—Apparatus constructed for comminuted fracture when no teeth are present in the mandible. (Courtesy of Major Kazanjian.)

If a large section of the bone is lost one sometimes can accomplish a satisfactory result by resecting the ramus and bringing the posterior part of

Fig. 107.—Roentgen picture of comminuted fracture showing splint and bone sutures. (Courtesy of Major Kazanjian.)

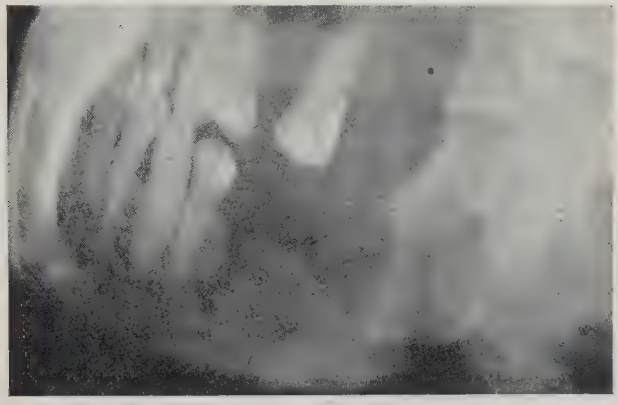


Fig. 108.—Roentgen picture of fracture at angle of mandible with loss of bone. If the fracture is reduced there will be enough contact at the inferior border to insure a good result.

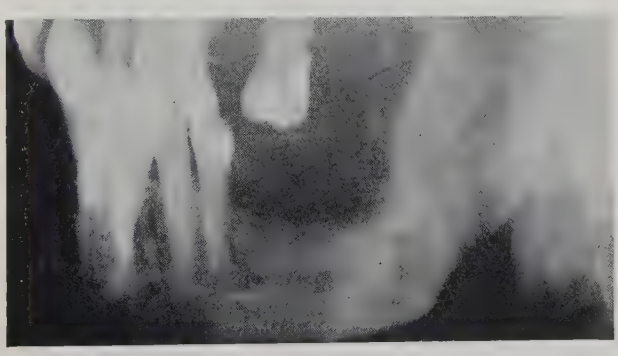


Fig. 109.—Roentgen picture of case shown in Fig. 108, taken one year later, which shows healing.

the body of the mandible forward. In the majority of such cases, however, treatment by bone-grafting is indicated (see p. 827). This must not be undertaken until the soft tissues have healed and all suppuration has entirely

disappeared, which includes the extraction of all infected teeth and putting the mouth into a thoroughly hygienic condition. The upper and lower jaws must be absolutely immobilized by means of interdental ligation or

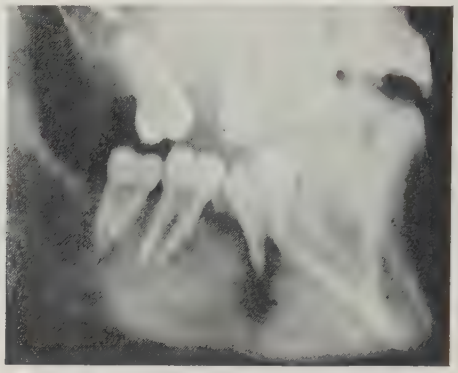


Fig. 110.—Roentgen picture of a fractured mandible showing non-union. Was treated seven weeks with interdental ligation, when an abscess formed, which was lanced. Swelling and pain did not disappear. Tooth found to extend between the fragments.

Fig. 111.—Case of malposition. The apparatus is designed to press the incisor teeth apart. When the condition has been corrected, the regulating device is removed, but the splint after being locked to retain the position is left until union has been completed. (Splint constructed by Harold J. Cutler.)

intermaxillary splints previous to the operation, which is described in a previous section.

Ununited and Malunited Fractures of the Jaws.—*Non-union* is generally due to one of three principal causes. The most frequent one is improper or

insufficient fixation or lack of proper contact of the fragments. Normal contact is often prevented by interposition of a detached piece of bone or a displaced tooth. Non-union may be caused by infection either from an involved non-vital tooth (Fig. 110) or occasioned by osteomyelitis.

In dealing with cases of non-union general diseases as contributing factors must be diagnosed and treated, and with the use of properly constructed splints most cases will in time unite. It may be necessary to freshen the surfaces of the fractures before treating the case under the new conditions. Instruments, the end of which contain a coarse file, have been devised for this purpose. If, after several months' trial, it is found that the case does not yield to this treatment, bone-grafting may have to be resorted to.

Malunion in its mildest form does not necessitate any treatment other than adjusting the occlusion of the teeth by grinding, or if there is any need, by the construction of bridges or adjustment of plates.

Malposition in cases of incomplete union, however, can be treated by orthopedic devices which will vary in each individual case. A great deal can be accomplished by means of springy wire or intermaxillary rubber bands used inside the mouth, or by more complicated extra-oral appliances, such as illustrated in Fig. 111. After the position has been corrected by the application of continuous force a locking device is used to hold the bones in place until union is complete.

Operative Procedures for the Reduction of Fracture of the Jaws

In cases requiring interdental ligation or intermaxillary splints all appliances and materials are prepared beforehand. In some instances this requires a day or two for the mechanical work, the fittings, and trials in the mouth.

Anesthesia.—In serious compound fractures and in cases with marked muscular trismus it is often necessary to use an anesthetic to reduce the fracture. If, as often is the case, a general anesthetic is desired, it is advisable to have the stomach washed thoroughly previous to the administration of general anesthesia. This washing of the stomach will reduce to a minimum subsequent nausea and vomiting. Wire cutters should be in readiness for use in case of emergency until the patient has entirely recovered from the effect of the anesthetic.

Local Anesthesia.—In the use of local anesthesia for the methods described hereafter the following solution has been found to give best results by the writer:

Procain	0.06	gram
L-Suprarenin synthetic	0.00006	"

This combination is contained in the "H" tablet made by the Metz Laboratories. One tablet containing the above amounts is dissolved in 3 c.c. of Ringer solution or normal saline solution.

Local anesthesia can be used to great advantage in many cases and does away with the dangers of general anesthesia. The nerve-blocking

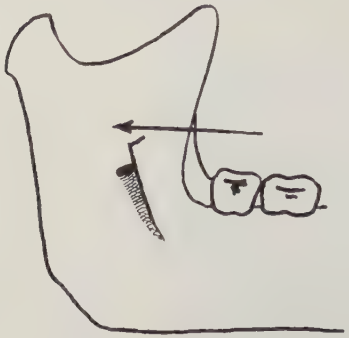


Fig. 112.—Conduction-anesthesia: Pterygomandibular injection.

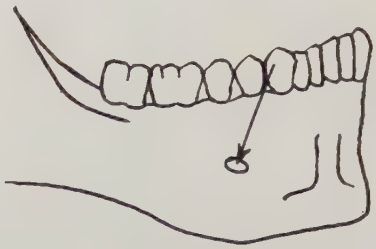


Fig. 113.—Conduction-anesthesia: Mental injection

Fig. 114.—Conduction-anesthesia: Zygomatic injection.

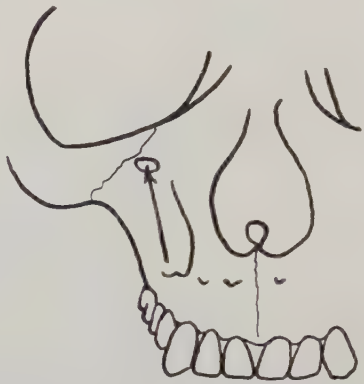


Fig. 115.—Conduction-anesthesia: Infra-orbital injection.

Fig. 116.—Conduction-anesthesia: Incisive and posterior palatine injections.

method can be used to advantage for both the upper and lower jaw. If there is much traumatism or a great deal of sepsis, extra-oral methods

should be chosen. Very marked trismus and induration of the tissues will also make the use of the intra-oral methods impossible.

The Pterygomandibular Injection.—The pterygomandibular space is the space between the internal surface of the ramus mandibularis and the pterygoid muscles and outlined by the sulcus mandibularis. In this space, which is filled with connective tissue, the interior alveolar nerve enters the mandibular foramen (Fig. 112). If this nerve is injected at this point, we get anesthesia of half the lower jaw, including the teeth and lower lip. The lingual nerve may be included in this injection, resulting in anesthesia of the lingual gum and side of the tongue.

The Mental Injection.—The solution is injected into the mental foramen to anesthetize the anterior portion of the inferior alveolar nerve (Fig. 113).

Fig. 117.—Extra-oral infra-orbital injection.

The Zygomatic Injection.—The three maxillary molars and soft tissues at the buccal side are supplied by the posterior superior alveolar branches, which can be reached and injected at the zygomatic surface of the maxilla (Fig. 114).

The Infra-orbital Injection.—By forcing the solution through the infra-orbital foramen into the infra-orbital canal, anesthesia of the peripheral distribution of the infra-orbital nerve, which supplies the anterior teeth and labial gum, may be secured (Fig. 115).

The Incisive Injection.—The nasopalatine nerve can be blocked where it emerges through the incisive foramen, resulting in anesthesia of the anterior third of the palate (Fig. 116).

The Posterior Palatine Injection.—This injection can be used to anesthetize the lateral half of the posterior two-thirds of the palate by blocking the anterior palatine nerve as it emerges through the larger palatine foramen (Fig. 116).

The Extra-oral Infra-orbital Injection.—The infra-orbital foramen can be palpated easily under the inferior border of the orbit. A very fine needle is inserted directly into the infra-orbital foramen from the surface of the skin (Fig. 117), a distance of about 1½ cm.

Fig. 118.—Extra-oral maxillary injection.

Fig. 119.—Extra-oral pterygomandibular injection.

It is important to make sure that the needle is not inserted into a vessel which would be indicated by discharges of blood. One and one-half c.c. is injected with low and even pressure. The anesthesia usually occurs in a very short time. The area anesthetized

includes the upper incisor teeth, labial part of gum, and the area supplied by the palpebral, nasal, and labial branch of the infra-orbital nerve.

The Extra-oral Maxillary Injection.—Palpate the superior border of the zygomatic arch and find the place where it forms a right angle with the superior margin of the orbit. This is called the "zygomatic angle." From this point draw a vertical line downward, and the point for insertion of the needle is about ½ cm. below the place where this meets the inferior border of the zygomatic arch. With the teeth in occlusion insert the needle with syringe mounted (Fig. 118). A few drops are injected under the skin. Advance in a vertical direction to the cheek for 2 to 3 cm. Here we strike the maxillary tuberosity. Sometimes it is necessary to direct the needle a little further backward to pass by the tuberosity which is felt for orientation and enter the sphenomaxillary fissure. After further advance of 2 cm. we again find bony resistance when the point of the needle strikes the inferior part of the anterior surface of the larger wing of the sphenoid bone, just below the foramen rotundum. The depth at this place is about 5 cm.—1 to 2 c.c. are injected. The injection is purposely made below the foramen to keep away from the nerves supplying the eye. After about five minutes the patient feels numbness in the nose, sometimes also in the upper lip, but the symptoms are much less marked than in the lower jaw. Complete anesthesia usually occurs in ten to fifteen minutes. The entire half of the upper jaw is anesthetized by this method.

The Extra-oral Pterygomandibular Injection.—This injection is made into the same place as the intra-oral one, namely, the pterygomandibular space. It is indicated whenever the intra-oral method cannot be used, as is often the case in fractures of the mandible and trismus of the muscles of mastication. The place to insert the needle is at the inner side of the lower border of the mandible, 2 cm. anterior to the angle of the ramus. Advance in a parallel direction to the posterior border of the ramus. After the needle has been inserted about 4 cm. we are in the pterygomandibular space, and as the direction of the needle is parallel with the nerve it does not matter if the needle is inserted a little too far. Inject 2 c.c. (Fig. 119).

The advance of the needle may find bony resistance in the depth of 3 cm. This comes from false direction of the needle point, striking a well-marked internal oblique line. The needle may strike bone at once, which may indicate a well-marked protuberance for the attachment of the pterygoid muscle. These mistakes are remedied by changing the direction of the needle. Numbness of the lip is felt about five minutes after the injection. Anesthesia takes effect in fifteen minutes, and the lower teeth and jaw and the lower lip and anterior part of gum on the side injected are anesthetized.

Alignment of the Fragments.—Besides bringing the fractured surfaces in good apposition the reduction of mandibular and maxillary fractures has another very important object, namely, the alignment of the teeth in normal occlusion. As a matter of fact, if the teeth are brought into normal occlusion we can rest assured that the fragments of the fractured bone are also in accurate position. If teeth which are infected, dislodged, or in the line of fracture have not already been removed, they should be extracted now before anything else is done.

The avoidance of sepsis in these cases is of paramount importance. If the wounds become septic, there is great danger of an extension of the inflammatory process to the deeper parts or even to the meninges of the brain. Lacerations of the soft parts—lips and cheeks—may have their edges approximated to secure less scar than if left unsutured. Loose small bits of bone should be removed with forceps and scissors.

In depressed fractures of the maxilla, if there is no wound of the skin and much depression of the jaw, so that the face is knocked in, it will be neces-

sary to devise some method of elevating the depressed bone and of restoring the normal contour of the face. To avoid a visible scar the mucous membrane should be incised on the inner side of the upper lip, and an attempt made to elevate the fragments by an instrument introduced through the incision. As little bone as possible should be removed, so as to leave sufficient support to the soft parts of the cheek after healing. Only thus can a falling in of the cheek be prevented.

If access through the mouth is unsuccessful, the antrum should be opened and intra-antral pressure made. Incision of the skin for reduction is to be avoided if possible. If this is found necessary, the method suggested by Lothrop should be employed. Access to the antrum is obtained by incising the mucous membrane in the upper part of the canine fossa. Introduce a curved blunt instrument, a urethral sound, into the outer corner of the antrum itself and raise the depressed malar by carefully applied pressure from within outward. The antrum should be packed with narrow strips of gauze saturated with vaselin to maintain the position of the fracture and to insure drainage of the antrum. The gauze should be left *in situ* for four or five days and then be gently removed.

Fractures of the alveolar part of the maxilla and all fractures of the mandible are reduced by digital pressure upon both fragments. The displacement is generally not very great, but the alignment must be correct for reasons already elaborated. When the reduction is completed it is made secure at once by means of the apparatus prepared for the case and described under the heading of fixation.

The Treatment of Septic Fractures

In septic fractures free drainage must be established. Abscesses which appear should be incised, their contents evacuated and an antiseptic dressing used. If the sepsis is caused by an infected tooth, this should be properly investigated by means of a Roentgen picture. If a sinus persists for several weeks, the existing sequestra should be removed. After a few weeks a more extensive necrosis of bone may occur at the seat of fracture, with abscess formation. These abscesses, often difficult to manage, occupy the region of the body of the jaw. The submaxillary and upper carotid triangles may be filled by a brawny infiltration associated with necrosis of a fractured jaw. On the other hand, with proper treatment and in less difficult cases the course of the healing process is simple and of easy management. Suppuration is prevented. There is no necrosis, and the repair of the fracture takes place unhindered.

After-care—Hygiene of the Mouth and Feeding

Some fracture cases require great care and good nursing, and the element of shock is important and must be carefully considered, especially in fractures of the maxillary bone.

An ice-bag may be applied to the face where the injury occurred—it is very helpful in keeping the swelling down. If the patient experiences difficulty in breathing, both through the mouth and nose, a spray of adrenalin chlorid such as is commonly used to shrink down the mucous membrane of the nose may be employed from time to time. This spray material may be prepared as follows: Take 1 dram of adrenalin hydrochlorid solution—1 : 1000—to which is added normal salt solution to make 1 ounce.

The mouth should be swabbed regularly—the best time is after feeding the patient, and as often as every four hours. The use of an antiseptic and deodorant is indicated. Eukatol, alcohol, or potassium permanganate serve well for this purpose. If the maxillary sinus (antrum) is involved, this should be irrigated gently with warm saline solution for the first few days. All accessible tooth surfaces should be brushed by the patient or the attendant and if possible the patient should visit the dentist every two or three days to have the mouth thoroughly sprayed by means of an atomizer. Only by the most vigorous effort can tooth decay and fetid and offensive breath be prevented under these adverse conditions.

Feeding of the patient must receive special consideration. The swallowing of foul secretions will impair the appetite, cause indigestion and general ill health, and the necessary loss of variety in diet often favors this condition. Out-of-door exercise, plenty of sleep, and a mild tonic, such as ferrated elixir calisayæ and sulphate of strychnin, and a little wine may be beneficial.

The first week or two liquids alone are to be given. Patients will generally be able to manage these very nicely. The liquids pass through spaces made by loose teeth, or if all teeth are present, behind the last molars. Later semi-solids may be added. If the patient cannot drink or sip through a glass tube a rubber catheter may be used behind the molar teeth. Nasal feeding is simply and easily carried out. A rubber tube 3 feet long is needed; to one end is attached a funnel and to the other end a soft-rubber catheter, No. 10 F. The patient is half-reclining while the surgeon introduces the catheter into the nose until it passes well back and down into the pharynx. The funnel, somewhat elevated a foot or more above the patient's head, is kept filled with the liquid nourishment so that its contents run slowly into the esophagus. A plug of absorbent cotton, moistened with a 4 per cent. cocain solution, and placed in the nose for a few minutes before feeding, facilitates this procedure.

Milk, raw eggs, egg and milk shakes, soft-boiled eggs, fruit juices, soups, chowders, beef extracts, cocoa, coffee and tea, tomato juice and later chopped meat and soft puddings will allow a variety of combinations for the meals of such patients.

AFTER-TREATMENT

The time required for the healing of fractures of the jaws has been discussed under the heading of Prognosis. After satisfactory union has occurred and the wires or splints are removed the patient must be cautioned to take proper care during the first few weeks until the bone is sufficiently strong to withstand unusual demands.

Many patients experience a stiffness and decreased motility of the mandibular joints following fracture. This may be due to changes in the joint as described under the heading of complications, or may be caused by spasm of the muscles. The cause of this is the inactivity during the period of fixation. It will generally disappear under ordinary use but the patient may be advised to specially exercise the jaw both in straight hinge and lateral as well as forward motion. Two fingers of one hand can be used to increase the distance to which the jaw can be opened. The thumb is placed palmar surface against the upper incisors, the index-finger against the lower teeth, pressing in the opposite direction. This is done at least twenty times every hour.

CHAPTER IV

FRACTURES OF THE VERTEBRÆ

Anatomy of the spine—General symptoms—Symptoms of fracture of regions—Prognosis—Operative treatment—Changes in the spinal cord following fracture—Lumbar puncture—The plaster-of-Paris splint—The prolonged convalescent care of a fracture of the spine—Bone-grafting in fracture of the spine—The Wallace method of fixation of the spine—Fracture of spine without neurological symptoms—Compression fracture of the spine—The care of the hopeless case of spinal fracture.

Anatomy.—The forked spine of the axis may be felt beneath the occiput upon deep pressure. The spines of the third, fourth, and fifth cervical vertebræ recede from the surface, and cannot be felt distinctly. The spines of the sixth and seventh vertebræ project distinctly and can be palpated. At the bottom of the furrow in the middle line of the back are felt the spines of the dorsal and lumbar vertebræ. The spinous processes from the seventh cervical to the third sacral are rather easily palpated. The spinal cord extends from the lower edge of the foramen magnum to the lower border of the body of the first lumbar vertebra. The phrenic nerve leaves the spinal canal between the third and fourth cervical vertebræ. By palpation through the mouth the bodies of the vertebræ may be felt down to about the upper border of the body of the fifth vertebra. The cervical enlargement of the spinal cord is more marked than the lumbar. It commences at the third cervical vertebra and ends at the second dorsal vertebra. The lumbar enlargement commences at the level of the ninth dorsal vertebra and reaches to the twelfth dorsal vertebra. The spinal cord is well protected from injury. Of spinal injuries as a whole, about 60 per cent. are fracture dislocations; about 20 per cent. are fracture alone; about 20 per cent. are dislocation alone without fracture (R. T. Taylor).

The vertebræ commonly fractured are the fourth, fifth, and sixth cervical, the twelfth dorsal, and the first lumbar. The injury to the vertebræ is caused in one of three ways: by a direct blow, fracturing the arches; by a fall upon either the head or the buttocks, crushing the bodies of the vertebræ; or by forced flexion or extension of the spine, causing a dislocation with or without fracture of the bodies and articular processes. More than one-half of the fractures of the cervical vertebræ are fractures of the spinous processes. More than two-thirds of the cases of fracture of the dorsolumbar vertebræ are fractures of the bodies of those vertebræ. A dislocation without fracture may occur in the cervical region; it is rare in other regions of the spine.

It is important in localizing spinal cord lesions to know the point at which each nerve arises from the spinal cord, because the point of origin does not correspond with that at which the nerve emerges from the spinal

canal. The point of origin is higher than the point of exit. Many of the nerves pass obliquely from the cord, lying still within the vertebral canal after leaving the cord. These nerves within the canal are liable to pressure

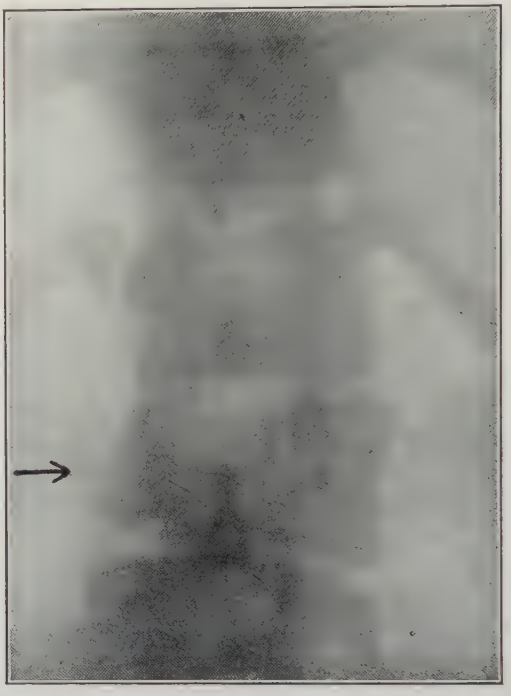


Fig. 120.—Fracture of the body of the first lumbar vertebra. Arrow points to vertebral body. Note the displacement of the two fragments.

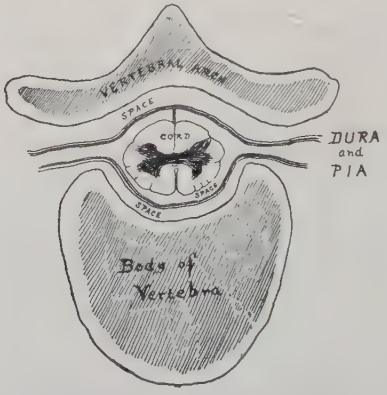


Fig. 121.—Diagram of a vertebra and spinal cord in horizontal section. Note that the cord is suspended within the bony canal. Note the great space between the cord and bony wall. Note that the cord is well protected against trauma.

from the vertebral fracture. For example, a fracture of the eleventh dorsal vertebra would injure not only the cord at this level, but, in addition, might injure the last dorsal and upper lumbar nerves. The lower the spinal nerves

arise, the longer is their intraspinal course. The points of origin of the spinal nerves from the cord with reference to the spines of the vertebræ are

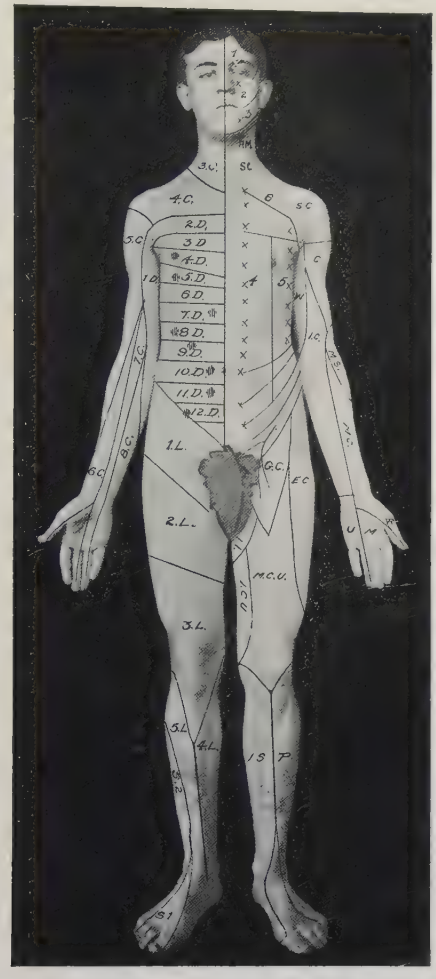


Fig. 122.—Anterior view of the areas of distribution of the sensory nerves of the skin (shown on the left side of the body), and distribution of sensation according to segments of the spinal cord (shown on the right side of the body): 1, Ophthalmic nerve. 2, Superior maxillary nerve. 3, Inferior maxillary nerve. The points of exit of the supra-orbital, infra-orbital, and mental nerves are shown by the markings ×. 4, Points of exit of the anterior intercostal branches of the intercostal nerves. 5, Points of exit of the lateral branches of the intercostal nerves. 6, Intercostohumeral nerve. *A.M.* and *S.C.*, Area of distribution of the great auricular, superficial cervical, and supraclavicular branches of the cervical plexus. *C*, Circumflex nerve. *W*, Nerve of Wrisberg. *I.C.*, Internal cutaneous area. *M.S.*, Musculospiral area. *M.C.*, Musculocutaneous area. *U*, Ulnar. *M*, Median. *R*, Radial. *G.C.*, Genitocrural area. The nerve is seen as distributing its branches to the genital region and to the upper portion of the thigh. *E.C.*, External cutaneous area. *I.I.*, Ilio-inguinal area. *I.C.U.*, Internal cutaneous area of the thigh. *M.C.U.*, Middle cutaneous of thigh. *I.S.*, Internal saphenous. *P*, External popliteal branches area. On the right side the division according to segments is seen, the letters *C*, *D*, *L*, and *S* standing respectively for cervical, dorsal, lumbar, and sacral segments of the cord. On the right side, from the fourth dorsal to the twelfth dorsal (inclusive), the maximum points, according to Head, of the abdominal viscera are shown in relation to the spinal segments. (Eisendrath.)

as follows (Fig. 122): The eight cervical nerves arise from the cord between the occiput and the sixth cervical spine. The upper six thoracic nerves

arise from the cord between the sixth cervical spine and the fourth dorsal spine. The lower six thoracic nerves arise from the cord between the fourth and tenth dorsal spines. The five lumbar nerves arise from the cord opposite to the eleventh and twelfth dorsal spines. The five sacral nerves arise from the cord opposite to the first lumbar spine. No hard-and-fast rule at present

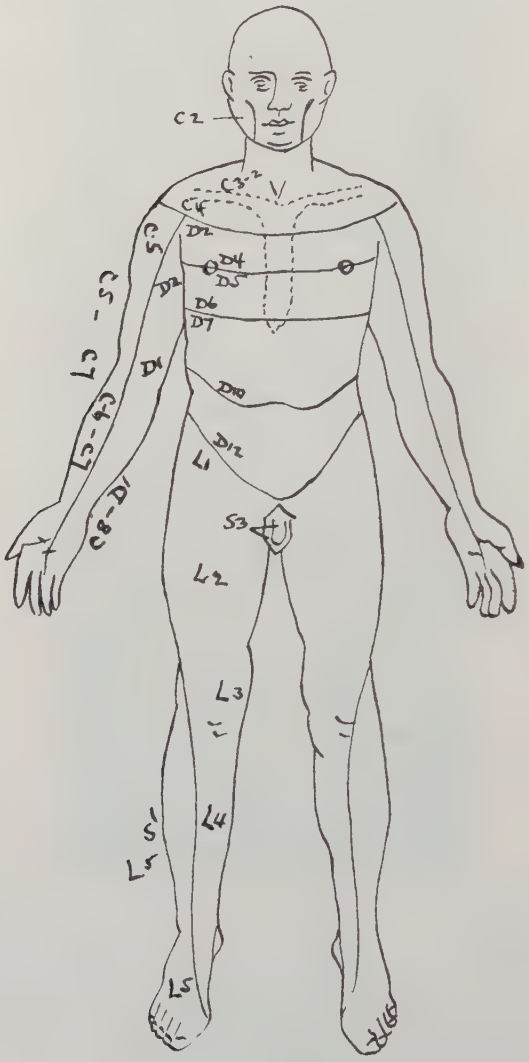


Fig. 123.—Cutaneous nerve supply to the anterior surface of the body (after Seiffer).

is applicable to the enumeration of the lesions following fractures and dislocations of definite vertebræ. From the combined experience of such clinicians as Gowers, Thorburn, Kocher, Putnam, Dennis, Walton, Bullard, Thomas, and others the following table is constructed, and is valuable for practical use:

TABLE STATING LESIONS FOLLOWING INJURY TO DEFINITE VERTEBRÆ

Spinal Segments.	Muscles Involved.	Vertebræ Dislocated.	Reflexes Involved.
Cervical:			
First, second, third	[Death].	Skull on atlas, atlas on axis.	
Fourth	Diaphragm.	Axis on third cervical.	Pupil is small and reaction sluggish.
Fifth	Biceps, supinators, deltoid.	Third on fourth.	
Sixth	Pronators, triceps.	Fourth on fifth.	
Seventh	Extensors, flexors of wrist.	Fifth on sixth.	
Eighth and first dorsal	Intrinsic muscles of hand.	Sixth on seventh.	
Dorsal:			
Second to twelfth	Intercostal and abdominal muscles (trunk).	.....	Epigastric, abdominal.
Lumbar:			
Second	Cremaster.	Eleventh on twelfth dorsal.	Cremasteric.
Third, Fourth, Fifth	Adductors. Outward rotators. Extensors of thigh, flexors of knee.	Twelfth on first lumbar.	Gluteal. Knee-jerk.
Sacral:			
First	Extensors of foot.	First on second lumbar.	Plantar and ankle-clonus.
Second	Calf muscles.		
Third, fourth, fifth	Perineal muscles.		

Examination of an Injury to the Spine.—Four questions are to be answered: What was the nature of the accident? What does palpation of the spine reveal as to the nature of the lesion? What is the level of the lesion? Is the lesion partial or complete?

General Symptoms Common to Fractures of the Vertebræ.—Signs of shock may be present. At the seat of the bony lesion will be found pain, tenderness, abnormal mobility, and sometimes crepitus and deformity. The deformity will ordinarily be a backward bending, or kyphosis, of the spinal column at the seat of fracture, unless there exists a unilateral dislocation, when the deformity will be irregular in appearance; the chief symptoms depend upon the injury done to the spinal cord. In general it may be stated that motor and sensory paralysis, either partial or complete, will be found up to the level of the lesion. The involved reflexes ordinarily below the lesion may be wanting at first and increased later. If a complete lesion is present the reflexes will be entirely wanting.

There may be temporary suppression of urine (Wagner). In lower thoracic fracture hematuria is sometimes met with independently of direct damage to the kidney substance. Retention and, later, incontinence of urine and feces will exist. Cystitis of the urinary bladder will develop at

an early date. Bed-sores and great sloughing areas of skin upon dependent parts will be discovered early. Priapism or a semiflaccid turgescence of the penis occurs. This is not a true "erection" of the organ.

Symptoms of Fracture of the Different Regions of the Spine, the Cord Being Involved.—*Injuries to the Last Dorsal and Lumbar Vertebræ* (Figs.

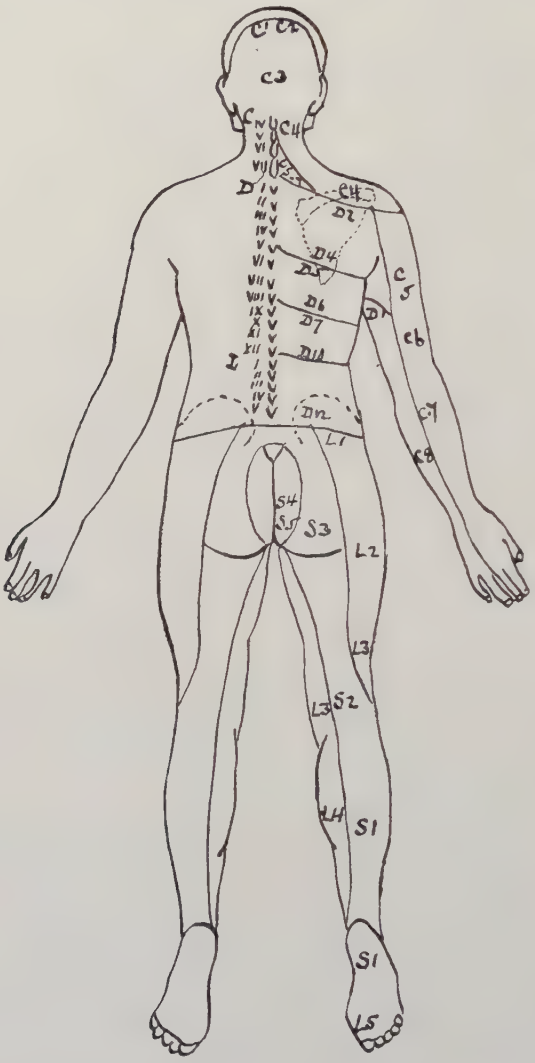


Fig. 124.—Cutaneous nerve supply to the posterior surface of the body (after Seiffer).

125–127).—The spinal cord ends opposite the lower border of the first lumbar vertebra. Any pressure at this point or below will involve the cauda equina in whole or in part (Figs. 128, 129). Local evidences of the bony lesions may be present. The paralysis of the legs may be partial or complete. The anesthesia of the lower limbs is partial rather than complete and up to the

Fig. 125.—Fracture of the twelfth dorsal vertebra. Anesthesia to the height of the anterosuperior spinous processes in front. Second lumbar nerve involved.

Fig. 126.

Fig. 127.

Figs. 126, 127.—Fracture of the twelfth dorsal vertebra without involvement of the first lumbar nerve-roots, the ilio-inguinal, iliohypogastric, and external cutaneous nerves not being involved.

Fig. 128.

Fig. 129.

Figs. 128, 129.—Injury to the cauda equina, which has involved the third sacral nerves. Fracture of the first lumbar vertebra or the second lumbar vertebra.

Fig. 130.—Sixth dorsal vertebra fractured. Anesthesia at the level of 2 inches above the umbilicus. The eighth or ninth dorsal nerve involved.

level of the bony lesion. Retention or incontinence of urine and feces exist. The paralyzed muscles rapidly become wasted. Constant pain and hyperesthesia may be present both above and below the lesion. The patellar and plantar reflexes are usually lost.

The prognosis is not altogether unfavorable to recovery. Partial recovery is possible. Later, muscular contractures will exist in the lower limbs, which impede walking. If at the end of six weeks evidences of beginning recovery do not appear, or if recovery once begun has ceased, it will be wise to operate upon injuries to the cauda equina.

Injuries to the Dorsal Vertebræ—Second to the Eleventh (Fig. 130).—The simple distribution of the spinal dorsal nerves below the first makes the interpretation of injuries to this region much easier than similar injuries to the cervical or lumbar regions. The arms escape paralysis. The motor and sensory paralysis extends ordinarily to the height of the bony lesion. In a few cases in which the nerve-trunks within the canal are not implicated the level of the paralysis will be lower than the lesion. The patellar reflexes are at first generally lost in the severer types of fracture. If the patient recovers, there will be spastic paralysis if the injury is above the lumbar

Fig. 131.—Lesion of spine between fifth and sixth cervical vertebræ. Note position of arms due to paralysis of subscapularis. Biceps brachialis anticus, supinator longus, and deltoid muscles intact. Elbow flexed, shoulders abducted and rotated outward (Cotton, after Thorburn).

enlargement. If the lumbar enlargement is involved, there may be great pain in the legs.

Injuries to the Cervicodorsal Region, Opposite the Cervical Enlargement of the Spinal Cord.—The arms escape paralysis, perhaps, at first, but become involved after several days. The paralysis is often partial. Respiration is diaphragmatic only. Pain in the arms is quite constant. If the sixth vertebra is dislocated upon the seventh, the intrinsic muscles of the hand will be paralyzed. If the fifth vertebra is dislocated upon the sixth, there will appear a characteristic position of the upper extremities (Fig. 131): abduction of the arms, flexion of the forearms, with rotation outward of the whole extremity. If the injury is above the sixth cervical vertebra, there will be anesthesia of the entire limb excepting the shoulder. The attitude after lesions between the sixth and seventh cervical vertebræ is shown in Fig. 132. The characteristic attitude in lesions between the sixth and seventh cervical vertebræ is also shown in Fig. 132.

Injuries to the Midcervical Region.—A lesion of the third cervical vertebra will involve the phrenic nerve. The diaphragm will be paralyzed. Death will occur within a few hours.

In the cervical and lower thoracic regions self-reducing dislocation without fracture frequently occurs. Clinically, we find an injured man showing no sign of fracture of the spine. There is a partial or complete paralysis

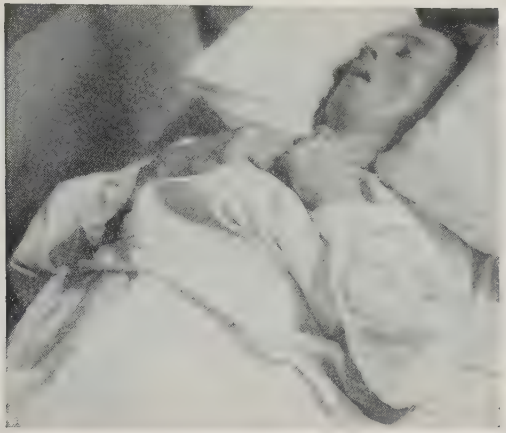


Fig. 132.—Luxation of sixth and seventh cervical vertebræ; typical attitude; center for subscapularis not involved. Contrast Figs. 131 and 132.

present. At autopsy no lesion of bone is found, but the spinal cord shows evidences of compression opposite an intervertebral disk in the cervical region. The cord may appear crushed through. There must have been a

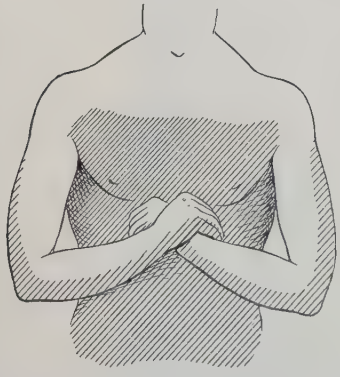


Fig. 133.—Lesion of spine between sixth and seventh cervical vertebræ. Position in case of complete transverse destruction of the cord just below nuclei for subscapularis; areas of anesthesia shown (Cotton, after Thorburn).

Fig. 134.—Atlas, axis, and third cervical vertebra from the front. Case: Man, thirty-eight years of age, fell from a cart. Fracture of odontoid process. Slight hemorrhage into the medulla. Death after forty-eight hours (Cotton and Cabot).

dislocation of one body upon another and an immediate reduction of the dislocation.

Injuries to the First Two Cervical Vertebræ (Figs. 134, 135).—If the displacement is slight, life may be spared until sudden displacement occurs or a secondary myelitis causes death. Cases of recovery are recorded. Death

usually occurs instantly. Perhaps one person in fifty thus injured recovers (Gowers). (See Dislocation of the Cervical Vertebra.)

Indirect violence is the common cause of injury to the first two cervical vertebræ. Direct violence, excepting a gunshot fracture, is unusual as a

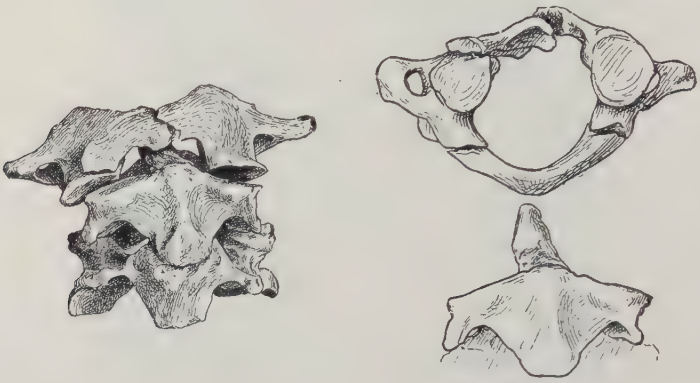


Fig. 135.—Fracture of the atlas and axis. Man, seventy-four years of age; fall; immediately left arm paralyzed. No loss of consciousness, speech thick. Neck movements normal. Twenty-four hours after the accident suddenly difficult breathing appeared and death followed (Cotton-Brooks).

cause of fracture of the atlas. This violence may be apparently very slight, from muscular action only. Sharp flexion or hyperextension of the neck is the ordinary form of violence in the causation of fracture. The most

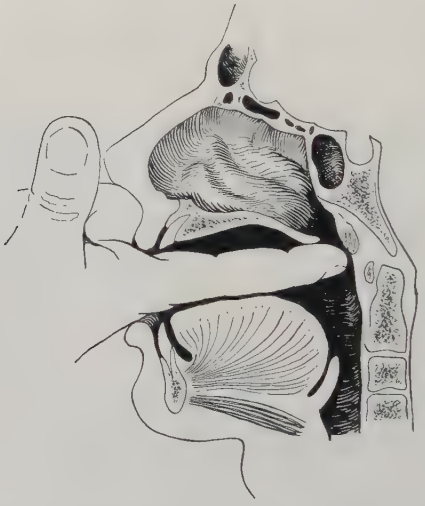


Fig. 136.—Diagram of palpation of anterior region of the first three cervical vertebræ through the mouth (after Davis and Peotti).

frequent lesion is a unilateral subluxation or true dislocation without fracture. (See Dislocation of Cervical Vertebra.) Fracture of the odontoid together with rotary dislocation is the next most common lesion.

The bone most commonly injured along with the atlas is the odontoid process of the axis. The second most frequent lesion associated with the

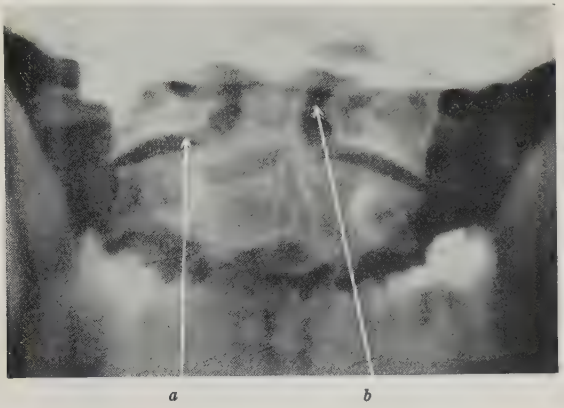


Fig. 137.—Roentgenogram through the wide open mouth. Note lateral masses, odontoid process, relation of the axis to the atlas; *a* points to the posterior arch and *b* to the anterior arch of the atlas. (George and Leonard.)

Fig. 138.—1, Body of axis; 2, posterior arch of atlas with foramen; 3, mastoid process and lateral mass of atlas superimposed on the odontoid; 4, odontoid process of axis; 5, anterior tuberosity of the atlas; 6, posterior tuberosity of the atlas; 7, parallel shadow lines show situation of retropharyngeal tissues. (George and Leonard.)

fracture of the atlas is a subluxation of the atlas in the axis. Then not infrequently there occurs an injury (usually a fracture) of a vertebra at some distance from the atlas.

Fracture of the atlas does not often involve the spinal cord, the cord lesion is ordinarily caused by the accompanying remote vertebral lesion.

The posterior arch is the weakest portion of the atlas since it is the most common seat of fracture. The anterior arch is the next most common fracture seat, and the lateral masses are third in frequency of fracture.

Early Symptoms.—These may vary from instant death to a simple stiffness of the neck and a slight asymmetry of the head position. The great occipital nerve passes under the posterior arch and the suboccipital nerve over the posterior arch of the atlas. Severe great occipital neuralgias and much rigidity with an increase of the pain on any attempted action or passive movement of the head are nearly always present and should lead one to suspect a fracture of the atlas. Inability to rotate the head is not pathognomonic of fracture of the odontoid; it may be a sign of fracture of the atlas.

Later Symptoms.—The rigidity and, as a rule, the occipital neuralgia persist. Sudden movement or attempts at reduction are often followed by immediately fatal consequences. The most serious changes may occur in the spinal cord, a myelitis, caused by pressure of bone or of callus. In Jefferson's series of atlas injuries 45.7 per cent. recovered.

Diagnosis.—The *x*-ray will demonstrate the lesion in a lateral view or, taken anteroposteriorly, through the wide open mouth. By this latter view an odontoid fracture may be demonstrated readily. Without an *x*-ray fracture of the atlas is often overlooked.

If it can be demonstrated that a simple unilateral dislocation of the atlas and axis has occurred, manipulation offers an opportunity for cure (see Dislocation of Cervical Vertebræ). Mixter and Osgood have recorded an operation for the relief of displacement of the atlas and axis due to a *fracture of the odontoid process*. No union took place in the fractured odontoid. At operation the arch of the atlas when replaced by backward digital pressure through the pharynx was held securely and fastened to the spine of the axis by silk passed about it. A good recovery followed with relief of the occipital neuralgia.

Cases of fracture of the arches of the first two cervical vetrebræ are best treated by absolute immobilization of the head.

A plaster-of-Paris molded splint applied from the back of the head to the neck and shoulders and back may well be the emergency means of treatment. Later a permanent splint may be fashioned. Three or four months is none too long in which to protect the movements of the head and high cervical spine after such a severe and dangerous injury.

I have one patient who is wearing permanently a Thomas collar after a fracture of the base of the odontoid process. It is a wise precaution to protect this vulnerable and vital region of the spine in a very rigid fashion.

Prognosis.—The prognosis depends upon the amount of injury to the spinal cord. The prognosis is less grave than it was thought to be a few years ago. There is a probability of saving a certain proportion of cases. In general, the nearer the fracture approaches the medulla oblongata and the foramen magnum, the more serious does the outlook become. Patients

with fracture in the dorsal and lumbar regions die in the course of months from cystisis, pyelitis, and exhaustion. Patients with fractures in the upper

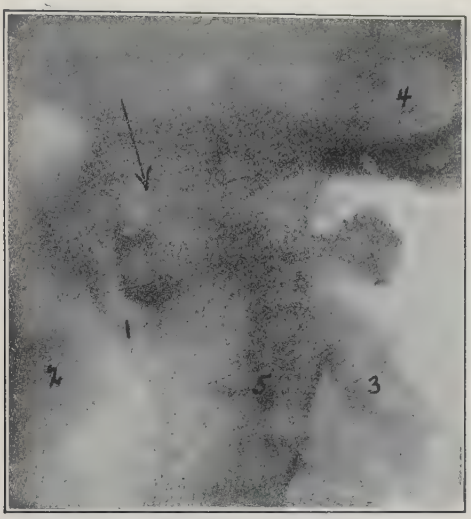


Fig. 139.—*x*-Ray lateral view of a fracture of the odontoid process with displacement. The arrow points to region concerned. Compare with Fig. 140 of normal plate. Numbering same as in Fig. 140. Note the relations between atlas and axis. (Case of Mixter and Osgood.)

dorsal and lower cervical regions die in a few days or weeks from hypostatic pneumonia. Patients with fractures high up in the cervical region die in-

Fig. 140.—*x*-Ray lateral view of a normal base of skull and cervical spine. The arrow points to region concerned: 1, Styloid process; 2, inferior maxilla, near its angle; 3, cervical spinous processes; 4, occipital bone; 5, body of vertebra. (Case of Mixter and Osgood.)

stantly or in a few hours from shock and direct pressure upon the medulla oblongata. After an injury to the back which prevents a man from rising,

he should be placed on a flat stretcher. The position assumed after the injury should be maintained, if it does not endanger life, until the surgeon sees the case. After examining the patient he should be aseptically cath-

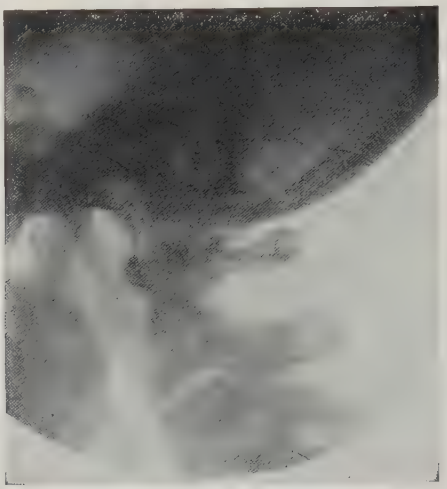


Fig. 141.—Normal spine, lateral view. Compare with Fig. 142 (George).

eterized. More accurate knowledge of the function of the kidneys will then be obtained during the first twenty-four hours.

Treatment.—The object of treatment is to relieve the cord from pressure and to immobilize the fracture. The cord will be uninjured, slightly injured,

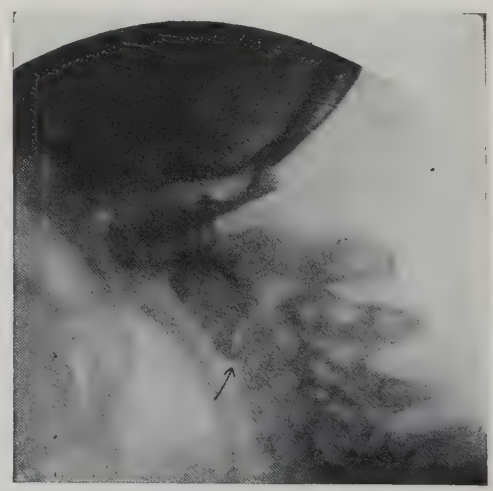


Fig. 142.—*x*-Ray of dislocation of the second cervical vertebra upon the third. See arrow pointing to dislocation (George).

or injured seriously. If the cord, judging by clinical signs, is uninjured, the bony parts may be left untouched or they may be replaced by manipulation or operation. If the cord is injured, the prognosis of operative interference

will depend upon whether the lesion of the cord is transverse and complete, or whether it is partial. Diagnosis is far behind operative procedures. The symptoms of a complete transverse lesion of the cord do not invariably indi-

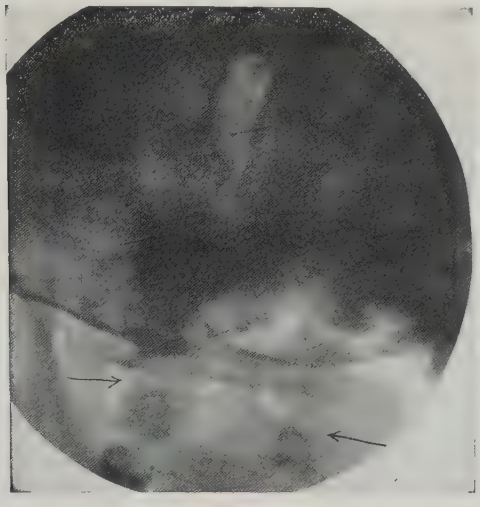


Fig. 143.—Unilateral dislocation of the atlas on the axis on the left side. See arrows (George).

cate a transverse lesion (Frazier). It is important, nevertheless, to distinguish between the signs of a transverse lesion and those of a partial lesion. In a complete transverse lesion the history of the onset of the symptoms is a sud-

Fig. 144.—Fracture of the odontoid process in an adult. Recovery. Stiffness of neck and limitation of motion remaining after injury. Arrows 1, 2, 3 point to the exact line of fracture at base of the odontoid process (Dodd).

den one, the symptoms appear immediately following the fracturing trauma; whereas if a partial injury is present, an interval will have elapsed before the symptoms develop; the appearance of symptoms is gradual rather than

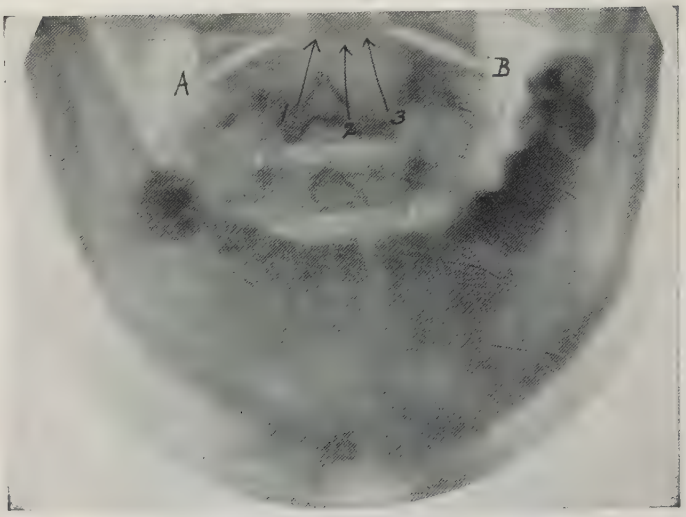


Fig. 145.—An *x*-ray of the first, second, and third cervical vertebræ in a normal neck. Compare *A* and *B* with similar lettering in Fig. 144. Arrows 1, 2, 3 point to base of the odontoid process. *A* and *B* mark articulations between atlas and axis (Dodd).

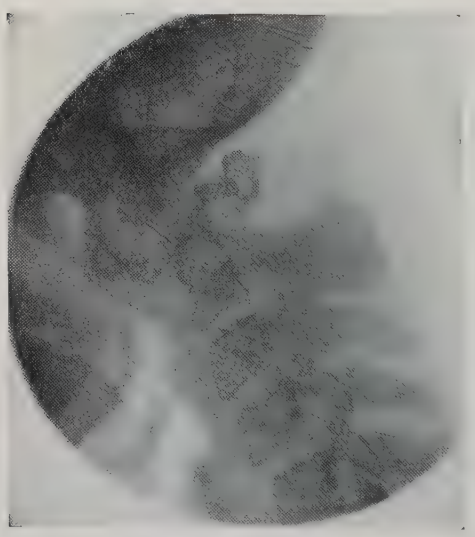


Fig. 146.—*x*-Ray of dislocation of the atlas on the axis (George).

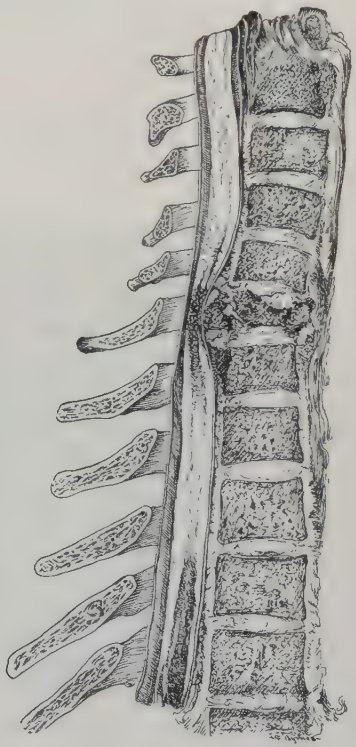


Fig. 147.—Fracture of the cervical spine; cord compressed by bone, torn and displaced intervertebral disk, and blood. Hemorrhage into the cord at the seat of the lesion and below the lesion (Warren Museum). (Drawn by Byrnes.)

sudden. In a complete transverse lesion the motor paralysis is found to be complete, and the paralyzed muscles are flaccid; whereas, if the lesion is a partial one, the motor paralysis is limited, some muscles of the limbs are paralyzed, others are not, and there is often noticed muscular spasm in the affected limbs. In a complete transverse lesion sensation is entirely gone;

Fig. 148.—Spine sawed in sagittal section, showing fracture through the intervertebral disk between the sixth and seventh cervical vertebræ, with dislocation forward of the upper fragment. Partial crush of the cord (Thomas).

Fig. 149.—Spine sawed as before. Fracture of the spinous processes of the seventh cervical and first and second dorsal vertebræ. Fracture of the bodies of the fifth, sixth, and seventh cervical vertebræ with displacement *backward* of the upper fragment. Total crush of the cord. The section passes a little to one side of the cord, which is seen in place, and the staining of the cord by hemorrhage into its substance shows plainly through the membranes even in the photograph. The spinous processes of the second and third dorsal vertebræ were found fractured at the operation, and were removed (Thomas).

whereas in a partial lesion some sensation is present. The knee-jerks are variable; in the complete transverse lesion they are absent. In the partial lesion the knee-jerks are apt to be absent at first, and they may return later.

Fig. 150.

Fig. 151.

Figs. 150 and 151.—Spine sawed as before. Fracture of spines of fifth cervical and fourth, fifth, and sixth dorsal vertebræ. Fracture of body of sixth dorsal vertebra. Displacement forward of upper fragment. Total crush of the cord, the softened substance of which has been removed by the saw, leaving only the empty and blood-stained meninges at this point. Figure 150 shows the spine as sawed; Fig. 151, the same hyper-extended, showing the obliteration of the narrowing of the spinal canal (Thomas).

In the transverse lesion the paralysis of the bladder and rectum is complete; whereas in the partial lesion paralysis of these organs is not always present. Priapism, sweating, and involuntary muscular twitchings are seen more

commonly in case of injury to the spine associated with complete lesions of the cord than in cases with partial lesions of the cord. In partial lesions variations from the definite types of symptoms are seen. The symptoms are more or less irregular. In total lesions of the cord operation may do good. The cases of pressure from fragments of bone—that is, those occurring for the most part in the cervical region, in which the laminæ of the vertebræ are fractured—demand operation. All other cases of bony pressure are

Fig. 152.

Fig. 153.

Figs. 152 and 153.—The two halves of the spine sawed in sagittal section. Fracture of the seventh cervical vertebra, with dislocation forward of the upper fragment. Fracture of the arch of the sixth and of the spine of the seventh vertebræ. Total crush of the cord. The discoloration of the cord from blood shows plainly in the plate (Thomas).

those due to dislocation of vertebræ which are remediable either by operation or manipulation. In these cases the prognosis depends upon the damage done the cord.

It is the result of experience that in cases of injury to the spine severe enough to do damage to the cord probably irreparable injury has been done by either a distinct crush of the cord or hemorrhage into the cord occurring at the time of the primary trauma. Hemorrhage into the cord takes place often extensively and some distance from the seat of the chief lesion, so that

even if the seat of the crush of the cord were reached by operation, damaging lesions would still remain unrelieved.

It is also a result of experience that removal by operation of the laminæ and spines of the vertebræ in the suspected region of fracture very rarely —almost never—reveals any remediable condition or affords any evidence of the exact seat of the lesions or their extent. In less than 10 per cent. of laminectomy operations for fracture of the spine is the patient benefited (Dandy). The reason for these facts is that the dura at the seat of a crush of the cord, whether partial or complete, remains intact and untorn, and that extradural hemorrhage is unusual. The surgeon, therefore, after removal of the laminæ, is as much in doubt as he was before, excepting that he knows that he has removed pressure from the cord and has diminished the likelihood of subsequent pressure. Operation in complete lesions holds out but little hope of benefit. It is said that the chances of the symptoms being due to pressure by extradural blood-clot or bone justify operative interference in these apparently hopeless cases. This is true in those cases in which the lesion of the cord is partial. When the lesion is completely transverse operation may relieve. If operation is to be performed at all, it should be done at the earliest possible moment. During a period of from twenty-four hours to seven days some good may be accomplished by operation. After a week or two have elapsed nothing can be accomplished in spinal cord injuries—unless it is in cases of nerve-root injury of the cauda equina.

Operative interference, then, may be summarized somewhat as follows:

In partial lesions operation may be demanded; in fracture of the laminæ and spinous processes operation is demanded; in all lesions of the cauda equina operation is demanded; in almost all supposedly complete lesions operation may be done with the hope of doing some little good. Explore all doubtful cases. Demonstration of a "bloc" and Roentgen ray may help to locate lesion.

The following position seems the wise one for the surgeon to take in cases of fracture of the vertebræ, particularly since a few cases have been recently recorded (notably Mixter's, reported by Chase) in which life was prolonged in comfort following operation in what appeared clinically to be a complete transverse lesion of the cord. The position here stated is that of Walton and the evidence existing supports its wisdom.

There are no symptoms which establish (otherwise than through their persistence) irremediable crush of the cord.

While total relaxed paralysis, anesthesia of abrupt demarcation, total loss of reflexes, retention, priapsim, and tympanites, if persistent, point to complete and incurable transverse lesion, the onset of such symptoms does not preclude a certain degree at least of restoration of function.

The prognosis without operation is grave.

While the results of operation are not brilliant, they are sufficiently encouraging to warrant us in making the practice more general.

In most cases it will be wise to operate within a few days, not later than ten days, of the injury, but a delay of some hours is advisable, partly on

account of shock and partly to eliminate the case of doubtful diagnosis. If at the first examination it cannot be determined whether the lesion is progressive or not, the findings are carefully noted, particularly the sensory changes. A few hours later the patient is again examined and a third time, if necessary. If the symptoms have increased laminectomy is indicated; if symptoms have decreased operation is contraindicated (W. J. Mixter).

We have no infallible guide to the extent of the lesion. The operation at the worst does not materially endanger life nor affect unfavorably the course of the case, and may at least reveal the lesion and lessen the pain; it may sometimes save a patient from death or from helpless invalidism of most distressing character. Instead of selecting the occasional case for operation, we should rather select the occasional case in which it is contraindicated (the patient with great displacement of vertebræ, the patient

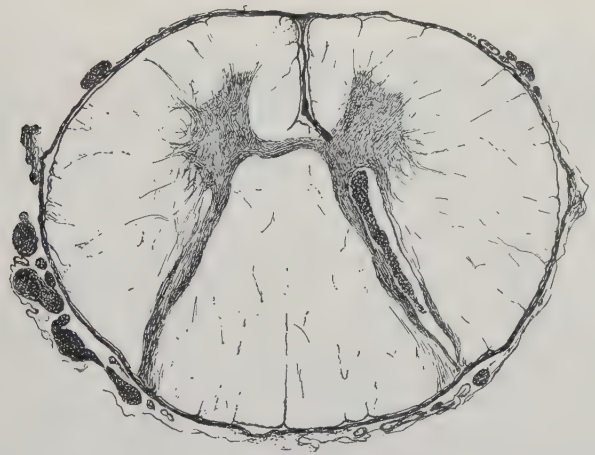


Fig. 154.—Man, fracture of spine; transverse section of spinal cord above the lesion. Complete paralysis below the lesion. Hemorrhage into posterior horn (Taylor). Trephining. Death in seventeen days. (Drawn by Byrnes.)

with high and rising temperature, the patient plainly moribund, the patient still under profound shock).

The dura should be opened freely; it need not be sutured; drainage is not necessary.

The fact that edema, congestion, inflammation of the spinal cord, or shock and infection (Spiller) may result from operation should not cause one to hesitate to operate in fracture of the spine.

Changes Occurring in the Spinal Cord Following Fracture or Dislocation of Vertebræ.—Regeneration never occurs: active inflammation which occurs during the healing of the gross tissues is never seen. There are never cellular and circulatory changes which are present in other tissues undergoing repair. The process consists of edema followed by liquefaction and vacuolation. It is an interesting fact clinically and pathologically that in cords compressed at a definite level with destruction of the cord, at the seat of compression there is often found a hematomyelia (hemorrhage into the sub-

Fig. 155.—Man, fracture of spine; transverse section of spinal cord above the lesion. Hemorrhage into posterior horn (Taylor). (Drawn by Byrnes.)

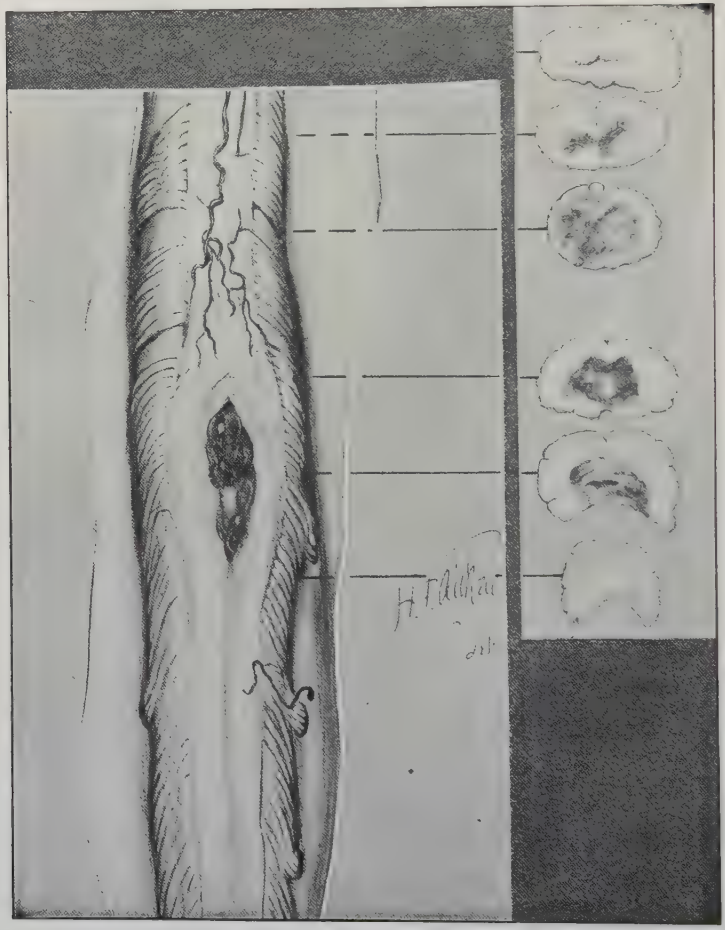


Fig. 156.—Fracture of the spine with crush of the cord. Hematomyelia some distance from the seat of injury. Dura intact. The third of the cross-sections shows the condition of the cord at the level of the crush. The paralysis was complete, yet at operation dura was intact (Walton).

stance of the cord), several vertebræ above and below the fracture, thus showing how extensive is the acting force.

A study of the drawings made from actual sections of the spinal cords of cases of fracture of the spine will indicate the different lesions already mentioned.

Figure 147 is from a fracture of the cervical vertebræ, showing destruction of the cord at the seat of the lesion, with localized pressure from bone and blood. Low down is seen an extensive extradural hemorrhage and a hematomyelia some distance from the original trauma.

Figure 154 is from a dislocation and fracture of the fifth upon the sixth cervical vertebra. There was complete paralysis below the lesion. Trephining was done. The patient lived without improvement seventeen days. This section of the cord is taken a little above the lesion and shows clearly a hematomyelia of the right posterior cornu.

Fig. 157.—Man, fracture of spine; transverse section of spinal cord at the seat of lesion (Taylor). (Drawn by Byrnes.)

Figure 155 is taken from a section of the cord of the preceding case a little below the lesion, showing complete destruction of the gray matter of the cord; the dura remained intact.

Figure 157 is also taken from a section of the cord of the preceding case, but at the seat of the lesion, showing a destruction of the gray and white matter of the cord anteriorly next to the bodies of the vertebræ. The dura remained intact, there being to the operating surgeon no evidence posteriorly of any disturbance having occurred anteriorly.

Figure 158 is a section of the spinal cord of a woman who fell from a trapeze to the net, and fractured and dislocated the sixth cervical vertebra. Operation was done. She lived three days. A little distance (two segments) from the seat of the lesion, where the cord was crushed anteriorly, was found a hematomyelia of the white matter posteriorly. The dura was intact.

These specimens, which illustrate the common lesions of the spinal cord following fractures and dislocations of the vertebræ, demonstrate the utter futility of operative interference in certain cases of crush of the cord with a complete transverse lesion.

The work of Reginald Allen on animals demonstrated that even if the cord were bruised sufficiently to cause permanent paralysis due to traumatic edema it would recover its function after a median longitudinal incision of the dura was made, thereby relieving intradural tension at once by the escape of edematous transudate. One case has been operated on by this method in the human, but the damage was high up and too severe to be permanently benefited. Some improvement in the treatment of these terrible injuries may come from this brilliant experimental work of Allen.

A careful study should be made of the cerebrospinal fluid obtained by lumbar puncture or by the combined puncture of the lumbar space and the

Fig. 158.—Fracture of the spine; transverse section of spinal cord several segments from the lesion; hemorrhage into the white matter (Taylor). (Drawn by Byrnes.)

cisterna magna (J. B. Ayer). This examination should include pressure readings, the evidences of shock, the presence of protein or blood in the cerebrospinal fluid—such accumulated data may prove valuable (W. J. Mixter).

It is to be hoped that in the future the present attitude which holds that operation on a fractured spine is often unsafe, rarely justifiable, and usually futile, may be favorably modified.

The Immediate Rectification of the Deformity and Immobilization by the Plaster-of-Paris Jacket.—With our present knowledge of the pathology of these fractures, and *excepting cases of fracture of the vertebral arch alone and pressure upon the cauda equina and partial lesions of the cord,* there can be no doubt that the most commonly applicable treatment for fracture of the vertebræ is by means of expectant methods. The methods are as follows: Immobilization of the part by a plaster-of-Paris jacket applied to the trunk

Fig. 159.—Partial fracture of twelfth dorsal and fracture of first lumbar vertebræ. Fall of 20 feet on nares. Paraplegia and sphincter paralysis. Death nine months after accident. Died of phthisis. Type of compression fracture (Warren Museum, Specimen 941).

Fig. 160.—Old fracture of twelfth dorsal vertebra. from fall of 13 feet; canal narrowed. Total paralysis of motion and sensation below injury. Died two years after accident (Warren Museum, Specimen 4629).

if there is no deformity. If there is deformity, correction of it and immobilization of the spine in the corrected position. The correction of the deformity must be immediate to avoid irremediable softening of the cord from pressure; and this may occur even within forty-eight hours.

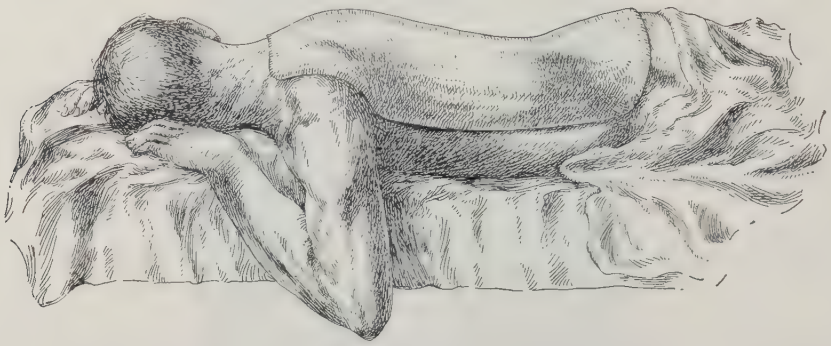


Fig. 161.—Application of plaster-of-Paris shell for fracture of the spine. In lesions above the sixth thoracic vertebra the shell should be extended to include the back of the head (Blake).

Occasionally it will be advisable to place the patient with a fracture of the spine without deformity prone and to apply a posterior back molded splint of plaster of Paris. This posterior plaster-of-Paris shell splint is to be held to the body by encircling swathe or bandage (Fig. 161).

Fig. 162.—Fracture of the dorsal vertebræ with great displacement of bodies. The patient lived two months (Warren Museum, Specimen No. 6229).

Method of Applying the Plaster-of-Paris Jacket.—This differs in no respect from the usual methods of application, with the exception that the patient should be protected from any unusual or sudden jar or movement. The trunk having been properly protected by a tightly fitting shirt, the

patient is carefully placed prone in the hammock. If the hammock suspension is not available, then the patient may be placed prone upon two kitchen tables, which are gradually pulled apart, allowing the trunk to be unsupported between the tables until the desired extension is obtained. If the tables are used, great care must be exercised that proper assistants secure the shoulders and hips of the patient during the procedure. Gentle, firm pressure is made upon the projecting vertebral spines until reduction is complete. The jacket, reinforced posteriorly by extra layers of bandage, is then applied. Death may occur instantly during this procedure, but if gentle measures are used, the likelihood of such a catastrophe will be mod-

Fig. 163.—Combination of compression and diagonal fracture of the fourth dorsal vertebra (Keen's Surgery, after Kocher).

ified. An anesthetic given to primary anesthesia is often of service. A sufficient number of assistants should be on hand—there should be at least four.

It is, of course, impossible to say what cases will be saved by this means, but it has been proved to be a life-saving measure in a few cases. The patient will be more comfortable and more easily managed after such a procedure. The hopelessness of the results of fractured spine justifies the surgeon in undertaking almost any risk.

Cystitis.—Life may be prolonged, if not saved, by the proper treatment of this distressing affection, which is always associated with fracture of the

Fig. 164.—Fracture of the fourth and fifth lumbar vertebræ. Compression of the spinal cord (Keen's Surgery, after Wagner and Stolper).

Fig. 165.—Fracture and subluxation; cervical vertebræ united (J. Mason Warren collection, Warren Museum) (Walton).

spine. In a number of these cases death is due to a pyelitis and nephritis following a cystitis. These complications may be avoided for a definite

time if the bladder is thoroughly drained by urethral catheter or by perineal drainage or by suprapubic cystostomy. The bladder may be kept aseptic by douching regularly with a solution of boric acid or permanganate of potash and by the internal use of urotropin. Great care should be exercised in the avoidance of bed-sores; it is easier to prevent than to cure them.

The Prolonged Convalescent Care of a Fracture of the Spine.—This care will cover the following considerations:

The placing of the patient in the best possible position for support to the spine with comfort.

Making the care of the skin at the pressure points easy and efficient.

Paying particular attention to the care of the function of the large bowel.

The devotion of every energy to encouraging all joint movements.

The prevention of any deformities, such as a foot- or toe-drop, stiffness and limited movements of the knee-joints.

Facilitating the transfer of the convalescing invalid into sunshine and an attractive environment.

Summary of Treatment.—Fracture of the arches of the vertebræ, whether open or closed, should be subjected to operation. Fracture and compression of the cauda equina after four weeks of waiting for spontaneous recovery should be treated by operation. In partial lesions of the cord operation may be demanded. All fractures showing doubtful complete transverse lesion of the cord should be treated by immediate operation. Only profound shock requires reasonable delay. The immediate fixation of the spine by a plaster-of-Paris splint is indicated in those fractures unoperated upon. It is also wise to fix the spine by the plaster-of-Paris splint after operation in many cases.

FRACTURE OF THE VERTEBRAL BODIES WITHOUT NEUROLOGICAL SYMPTOMS

A compression fracture of the vertebral bodies may result without permanent damage to the spinal cord.

The general story is somewhat as follows: A spinal injury is received. There is some shock. There are a few signs of painful back, possibly tenderness, all temporary, however, clearing up following lying in bed a few days. The short duration of these suddenly appearing symptoms following injury to the back, without any local lesion discernible, is quite characteristic. After a varying time of several weeks or months, or even years perhaps, a group of delayed symptoms will appear. These delayed symptoms are of very great importance and incapacitate the individual absolutely. These symptoms are those of pain, disability in using the back, Roentgen-ray evidence of damaged vertebral body or bodies, and the appearance in the damaged vertebral region of a distinct kyphos.

At the very outset following the injury the Roentgen-ray findings will often be absolutely negative and subsequently, when the delayed symptoms appear, the Roentgen-ray findings will be clear and definite and positive. Such may be the course of these cases of injured back. They form a small, very important, group of cases from all angles.

Such a compression fracture or crush fracture may be unrecognized and, therefore, go essentially untreated. Many physicians think wrongly that if a man can walk he has not fractured his spine.

The damage to the spine results from either direct violence or from indirect violence. The most common cause is from indirect violence as seen in the hyperflexion or hyperextension of the movable part of the spine or the more immovable part—the cervicothoracic junction and the dorso-lumbar junction.

The fractures which go unrecognized occur usually in the fixed regions of the spine—the thoracic and lumbar regions.

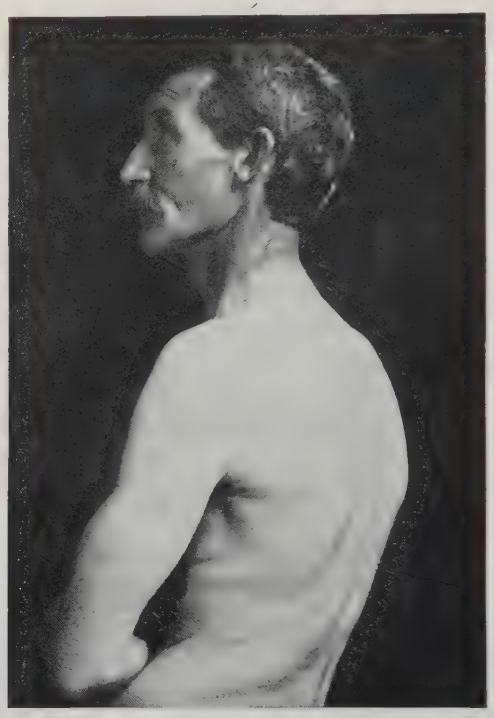


Fig. 166.—Case I. Fracture of first lumbar vertebra showing typical attitude (Roberts).

The following lesions occur: crushing of the body of the vertebra, rupture of posterior ligaments and muscle, rupture of anterior ligaments, rotation of vertebræ.

In some recorded cases a heavy object ("roof coal") struck the patient from above while the spine was slightly flexed in work. In some cases the patient fell from a height, striking the ground on his head or shoulders. Falls from trestles, from scaffolds, from buildings, down elevator shafts, diving accidents are among the causes of fracture. In some cases the patient was squeezed in the bent or flexed position—as when a man is caught between the jamb of a barn-door and a load of hay.

After severe trauma capable of causing crushing fractures of the spine associated injuries may be the apparently important lesion when really the associated lesions are of minor importance.

The healing of these crushed spines is attended by the formation of bridges of bone laid down from one vertebra to another. Sometimes this bridge of bone is formed laterally, sometimes anteriorly to the vertebral body. In about 33 per cent. of the series recorded by Wallace this bridging by bone of the fractured region was found (see Fig. 174).

Symptoms.—Back pain, a kyphos, weak back, inability to lift may be present. In most cases extension of the spine was most restricted. Normal hyperextension of the spine was impossible either actively or passively. Lateral bending was limited. Forward bending was not restricted to any very marked degree. In old cases muscle spasm is not usually present. Tenderness on pressure over the spinous processes of the injured vertebræ is a quite common symptom in recent cases and is present for some time in old cases. These signs and symptoms may not all be present at any one time. They may appear gradually and quite a long time (weeks or a month or more) after the injury.

The ninth, eleventh, and twelfth dorsal vertebræ and the various lumbar vertebræ are the vertebræ usually fractured. About 60 per cent. of fractures of the spine are below the tenth dorsal vertebra.

In most of these crush fractures the vertebra above the damaged vertebra is the one through which the fracturing force is applied.

Treatment.—It is important even if a patient has been kept in bed for some time that in getting up he have a proper support to the spine. This support will prevent deformity as well as facilitate eventually the full functional movement of the spine. The deformity present should be as nearly as possible corrected ordinarily by hyperextension and held supported for about six months.

The Wallace Method of Fixation of the Spine.—Most of the cases have been deformed by flexion of one portion of the spine on the other. The principle of treatment has been to hold one fragment in the correct position and make the other fragments straighten in the reverse of the steps taken in producing the deformity.

The lumbar spine is fixed (*i. e.*, the lower fragment); this includes the spine from the site of fracture and the two lower extremities to the soles of the feet. This is accomplished by fastening the feet to the bottom of the bed frame (devised by Wallace for this purpose). The lower fragment is held horizontally by elevating this lower fragment, the upper fragment drops backward and downward. Thus is obtained extension and counterextension.

The principle of the treatment differs from that on the Bradford frame in that the lumbar spine is held straight, relaxing the flexors of the pelvis and a lordosis is avoided when the upper fragment is hyperextended and the deformity is unfolded.

Every case of suspected fracture of the spine should have anteroposterior and lateral Roentgen-ray plates taken.

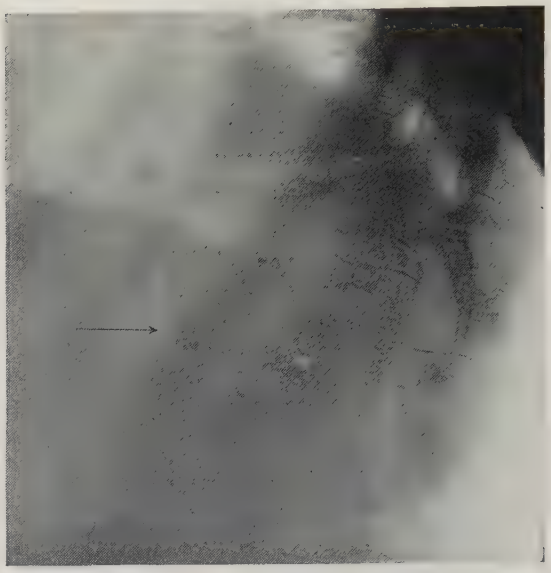


Fig. 167.—Case I. Fracture of first lumbar vertebra with displacement of fragment (Roberts). Compare with Fig. 166.

Fig. 168.—Case II. Fracture of sixth and seventh dorsal vertebræ with rounded deformity of spine (Roberts)

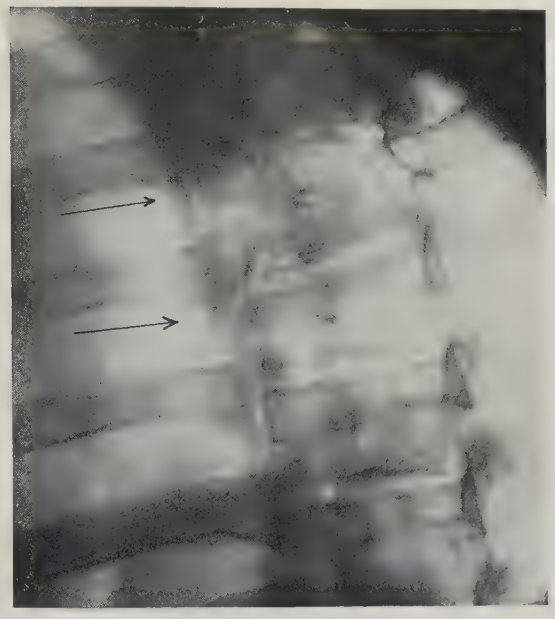


Fig. 169.—Anteroposterior view showing crushing of the two dorsal vertebræ (Roberts).

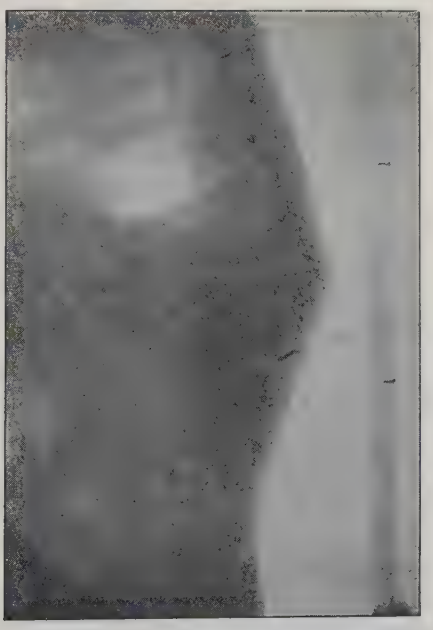


Fig. 170.—Showing side view of spine with deformity taken in the ordinary way (Wallace, Jour. Bone and Joint Surgery, January, 1923).

It is unnecessary to do any primary spinal bone plastic fixation operation in these cases. If the individual is not treated at all or is ineffectively

Fig. 171.—Showing side view of the spine with the legs flexed on the abdomen to hold the lumbar spine straight, thus throwing the deformity in the upper fragment. This is the best way to take an *x*-ray in order to determine how much deformity really exists in a spine (Wallace, Jour. Bone and Joint Surgery, January, 1923).

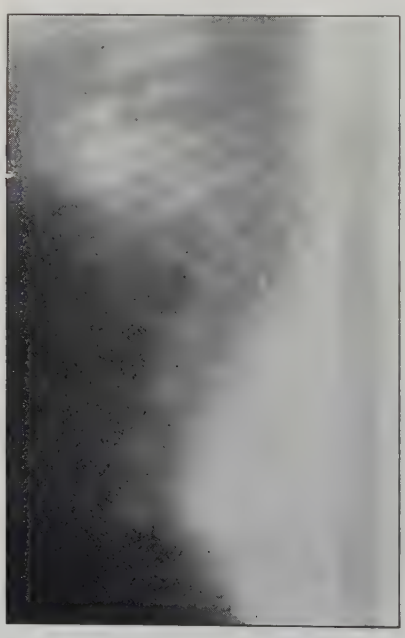


Fig. 172.—Showing a side view of the spine with the dorsal spine held straight, thus throwing all the deformity in the lower fragment or lumbar spine. This is the position in which the patient is placed in the Wallace frame for the application of a body cast (Wallace, Jour. Bone and Joint Surgery, January, 1923).

treated, as happens too often, then he becomes a chronic invalid with a persistently lame and weak back.[1]

The emergency and expectant method of treatment by fixation of the spine may give temporary relief, in a few cases permanent relief. In some

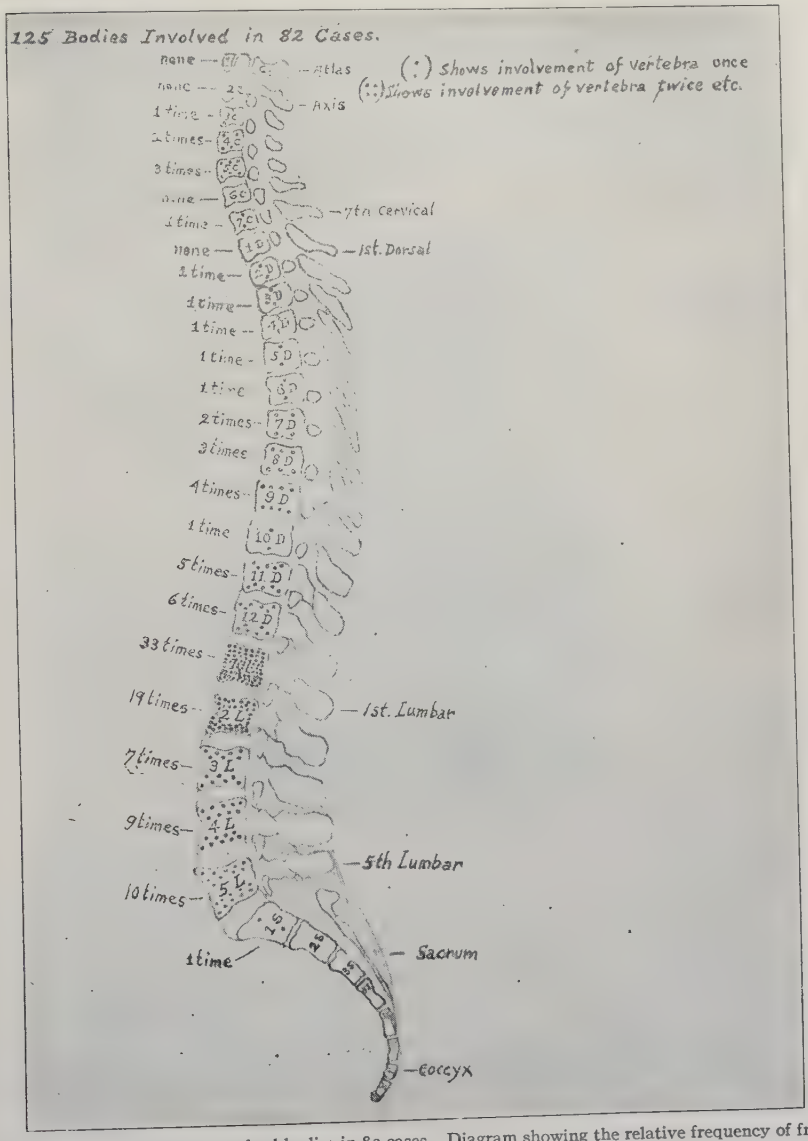

125 Bodies Involved in 82 Cases.
(·) Shows involvement of vertebra once
(:) Shows involvement of vertebra twice etc.
none — 1C — Atlas
none — 2C — Axis
1 time — 3C
2 times — 4C
3 times — 5C
none — 6C
1 time — 7C — 7th Cervical
none — 1D — 1st. Dorsal
1 time — 2D
1 time — 3D
1 time — 4D
1 time — 5D
1 time — 6D
2 times — 7D
3 times — 8D
4 times — 9D
1 time — 10D
5 times — 11D
6 times — 12D
33 times — 1L
19 times — 2L — 1st. Lumbar
7 times — 3L
9 times — 4L
10 times — 5L — 5th Lumbar
1 time — S — Sacrum
Coccyx

Fig. 173.—Fracture crush of vertebral bodies in 82 cases. Diagram showing the relative frequency of fracture involving the various individual vertebræ (Wallace, Jour. Bone and Joint Surgery, January, 1923).

cases operative treatment will be found to be necessary even after the temporary treatment has been carefully carried out.

Bone-grafting of the spinous processes does afford remarkable relief from

[1] Wallace, Journal of Bone and Joint Surgery, January, 1923.

symptoms, and that quite strikingly soon after operation, but it has not been adequately proved that this relief is permanent. Many cases with primary relief subsequently have serious trouble referable to the back. Operative spinal fixation may undoubtedly be indicated in old cases inadequately treated at the outset.

It is an interesting observation that a severe spinal crushing injury may clear up and give permanent cure after protective treatment when less severe injuries are more resistant to protective and expectant care, even though the treatment be skilfully conducted.

Compression Fracture of the Spine May Develop Delayed Symptoms.—Post-traumatic spondylitis, Kümmell's disease, developing as a result of

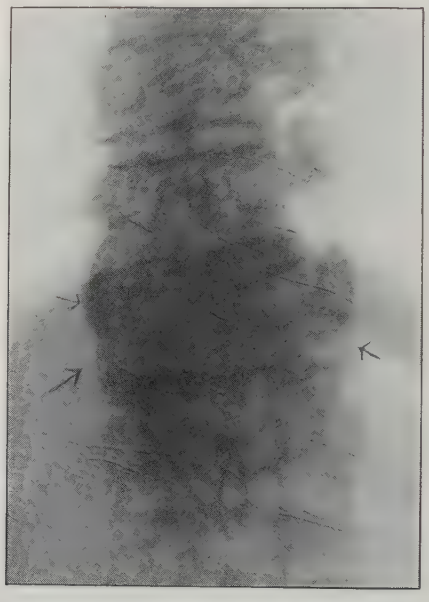


Fig. 174.—Case G. F. Aged fifty-seven, laborer. Fell 20 feet, landed on shoulder, head between legs Angular deformity. Crush of eleventh dorsal vertebra, more on the right side laterally. Dislocation of the eleventh dorsal vertebra to the left on the tenth dorsal vertebra. Note dense healing and lateral bone bridges (Wallace, Jour. Bone and Joint Diseases, January, 1923).

compression fracture of the spine is a distinct entity. It occurs both in children and adults. The youngest case reported is a child eight years old (Hirgens).

It is important that a thorough examination of these cases of vertebral injury, without cord lesions, be made, including a record of the neurological and roentgenological findings.

Kümmell believes that a rarefying osteitis (acute bone atrophy) following traumatism is not the sole result of the trauma, but that the trauma may be a mere contusion of the spongiosa of the body of the vertebra with hemorrhagic infiltration and periosteal thickening. There may be no clinically demonstrable lesion, yet distinct symptoms may develop after months or years following the original untreated trauma.

The *prognosis* is favorable to a cessation of any steps toward Kümmell's disease if the treatment by adequate protection of the injured spine is carried out. Three distinct stages of Kümmell's disease are recognizable: (1) The stage of initial injury to the spinal column associated with varying degrees of shock. If treated during this stage all further progress of Kümmell's disease may be arrested. (2) The stage of "relative well-being"—the patient attends to his duties and occupation. This is the time when the physician overlooks the seriousness of the original trauma. (3) The third stage, when after weeks, months, or three years have elapsed, an angular kyphos appears.

Local back pain or pain neuralgic in character, sometimes radiating down the extremities, appears. These symptoms are all relieved by rest in the recumbent position.

Roentgen examination should be made in anteroposterior and lateral planes.

The *differenal diagnosis* from tuberculous spinal caries, back strains, spinal neuroses, hypertrophic arthritis, and the true ankylosing type of spondylitis must be carefully considered.

Prevent Kümmell's disease[1] by recognizing and adequately treating compression fracture of the bodies of the vertebræ.

GUNSHOT FRACTURES OF THE VERTEBRÆ

These open fractures arrange themselves into three groups for practical purposes:

First group: Those cases in which the viscera of the thorax or abdomen are simultaneously injured.

Second group: Those cases in which the bullet has entered the spinal canal and has injured the spinal cord.

Third group: Those cases in which the spines and laminæ or the arches of the vertebræ are injured.

Treatment.—In all cases the external wound should be carefully cleansed and protected by an antiseptic dressing.

The degree of shock should be observed. Shock should receive adequate early treatment.

Any signs of a lesion of the cord should be noted.

Evidences of damage to the viscera within the chest or abdomen should be sought for.

In the absence of great shock it is wise for the surgeon, under antiseptic and aseptic conditions, to lay open the wound, to thoroughly disinfect it, and to attempt to ascertain the condition of the cord and vertebræ. If the symptoms point immediately to a transverse lesion of the cord, extensive operation is contraindicated.

The character of the damage done by the bullet to the vertebræ and spinal cord cannot be wholly determined except by operation. In operating there is always the possibility of diminishing the chances of infection

[1] Frederick Jones, Jour. Amer. Med. Assoc., December 1, 1923.

through the bullet wound and of relieving pressure upon the spinal cord from blood-clot and fragments of bone.

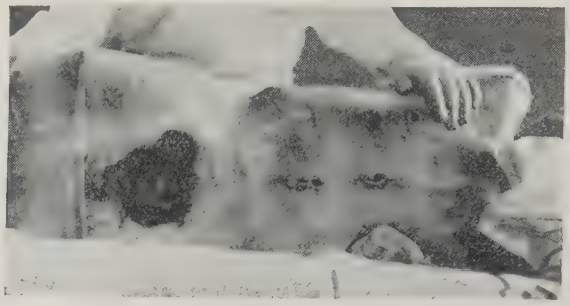


Fig. 175.—Decubitus following fracture of the spine. The large bed-sore exposes the sacrum and the posterior wall of the rectum. The wound margins are undermined for a considerable distance by sloughing, necrotic tissue. (Service Unit 1, Washington University, City Hospital.) (Kirchner, Surg., Gyn., and Obst., June, 1923.)

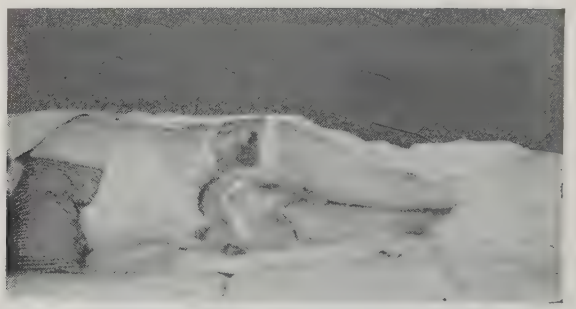


Fig. 176.—Strong, well-padded and comfortable plaster shell applied to the back and held in position by a sand-bag. The shell is cut away at the lower part to relieve pressure over the bed-sore and to permit of easy dressing of the wound. (Kirchner, Surg., Gyn., and Obst., June, 1923.)

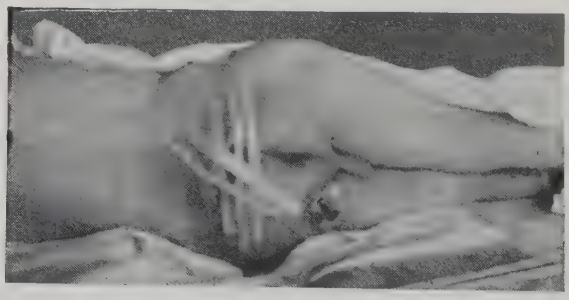


Fig. 177.—Method of supporting and treating bed-sore by means of strapping, lattice fashion, with adhesive strips. The traction assists in the healing process and greatly diminishes the size of the bed-sore by approximating the true skin margins. (Kirchner, Surg., Gyn., and Obst., June, 1923.)

A crushed cord is not incompatible with life. Such a patient may live for several months or even for several years. Operation may prevent death from sepsis even if a crush of the cord exists.

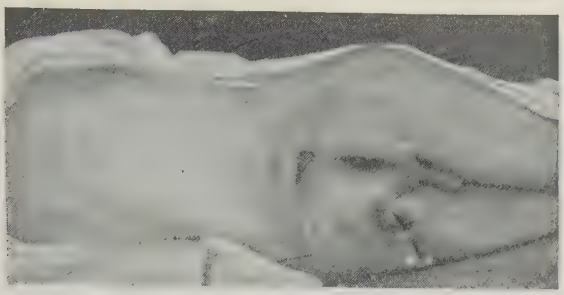


Fig. 178.—Effect of treatment on a bed-sore which was over 5 inches in diameter. Wound almost entirely closed in by true skin. A deep, perforating trophic ulcer over the left tuberosity is indicated by a rubber tube for treatment with Dakin's solution. (Kirchner, Surg., Gyn., and Obst., June, 1923.)

Fig. 179.—Frame roughly made to facilitate handling of the patient. (Kirchner, Surg., Gyn., and Obst. June, 1923.)

Fig. 180.—Method of supporting lower extremity by means of soft pads and pillows to prevent bed-sores. The heel should be kept free to avoid pressure sores. The atrophic muscles are massaged daily. All joints are manipulated. (Kirchner, Surg., Gyn., and Obst., June, 1923.)

Care of a Case of Fracture of the Spine, Other than Operative Care.—These suggestions are made with regard to the care of individuals with the graver lesions of the cord in which there is a definite paralysis.[1]

[1] Kirchner, Surg., Gyn., and Obst., June, 1923.

Fig. 181.—A suitable fracture-bed permitting the easy elevation of trunk to sitting position and the satisfactory use of a bed-pan by lowering the middle section. The trapeze enables the patient to lift himself, thereby materially assisting the nurse in the care of the patient. An elastic supporter may be used to correct foot-drop. (Kirchner, Surg., Gyn., and Obst., June, 1923.)

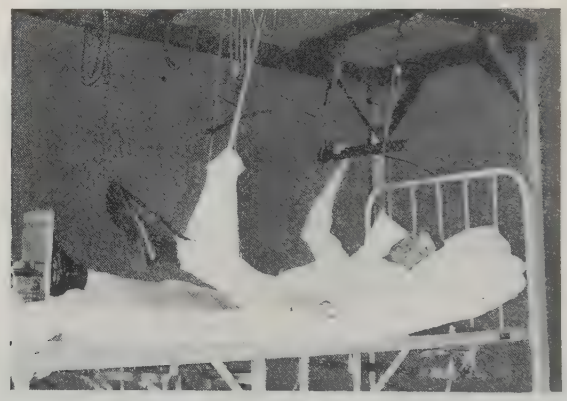


Fig. 182.—The frame enables various types of apparatus and treatments to be put to use. The sling for the leg permits of easy adduction and abduction of the lower extremity. The foot is always supported so as to correct foot-drop. (Kirchner, Surg., Gyn., and Obst., June, 1923.)

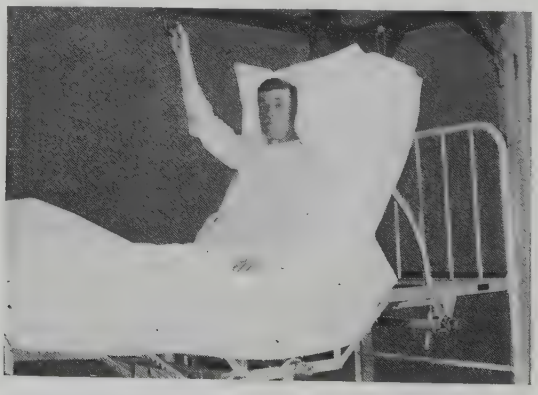


Fig. 183.—Patient in plaster-of-Paris shell elevated to sitting position, thus relieving pressure on the back. The position improves the circulation and the general health of the patient. He is also thus enabled to feed himself. (Kirchner, Surg., Gyn., and Obst., June, 1923.)

The primary treatment has been considered in the preceding pages, *i. e.*, the treatment of shock, the attempt at reduction of the fracture dislocations, or removal of pressure on the cord by operation.

The treatment during the days of convalescence and often many days preceding death is a very important phase of these desperate cases.

The treatment will be directed to the urinary bladder, the rectum, the lung, the heart, the local skin disturbances from trophic changes, bed-sores, edema, abscess, neuritis, atrophy of muscles, the prevention of infection, and sepsis. Certainly this is an appaling group of possibilities.

The Bladder.—A bad cystitis is to be avoided. Unless the pain and bladder distention are too great catheterization should be avoided. Overdistention of the bladder with incontinence is safer than faulty catheterization.

When catheterization must be resorted to the bladder may be irrigated with a sterile saturated warm boric solution, followed by a mild antiseptic solution. The question of a permanent drainage of the bladder, suprapubic or perineal, will have to be faced, possibly.

The *incontinence of feces* can be controlled fortunately by the timely use of a gentle laxative. A daily cleansing enema will keep the patient clean and the rectum well disposed.

Bed-sores, the result of trophic change and continued pressure, are to be combated by the care of the probable sites of such lesions. The skin is to be bathed regularly and repeatedly with alcohol and powders used—to toughen the skin. These are better materials than oils and ointments.

Ulcers and Sloughing Areas.—These are adequately treated by Dakin's solution or hychlorite solution.

Ulcers, after having been cleaned of sloughs, may be hurried a bit in their repair by appropriate strapping. Scarlet red ointment is useful in stimulating epithelial growth. Balsam of Peru in castor oil (3 parts to 1 part) is helpful to stimulate sluggish granulation tissue. An aluminum potassium nitrate poultice is useful (see Fig. 161). *Massage* of the entire body daily is called for.

Appropriate splints and supports are to be made for the problems that arise—all calculated to prevent contracture deformities, to facilitate moving about a bit and to cheer the justly often discouraged patient.

A properly applied plaster-of-Paris back "shell" is helpful, affording even pressure and being easily removed for the care of the skin over bony prominences.

An *adjustable fracture* bed is almost essential to the proper handling of these cases (see Fig. 181).

The Nursing of the Patient.—A primary "hopeless case" discourages the nurse. The nursing should be suspervised by the attending surgeon in every small detail. This personal responsibility manifested and assumed by the surgeon will fortify, stimulate, and greatly assist the nurse in her work.

The genitalia hair of the patient should be shaved for cleanliness sake. The urinal should be of the proper type to avoid leakage and soiling.

The bed must be dry, clean, and smooth.

The nourishment, food, and ventilation should all have due consideration.

Fig. 184.—In the recumbent position the seat of the swing is placed under the buttocks. When the patient is raised to the sitting position the ropes and pulleys of the swing are adjusted. The back-rest having been lowered, the patient in the swing is easily elevated, the bed is removed to one side and in its stead is placed a roller-chair into which the patient is lowered. The bed-ridden patient is thus enabled to get about. (Kirchner, Surg., Gyn., and Obst., June, 1923.)

Fig. 185.—Locomotion is possible by means of the "perambulator" which when placed a short distance in front of the patient, enables him to drag himself forward or to take steps as in walking. The patient's back is supported by a corset which is specially designed. (Kirchner, Surg., Gyn., and Obst., June, 1923.)

Fig. 186.—The patient is also taught how to use crutches and in the beginning the tripod method of locomotion is most useful. The upright position permits the bed-sores to heal more rapidly. Weight-bearing strengthens the knees and also seems to re-establish the sense of equilibrium. (Kirchner, Surg., Gyn., and Obst., June, 1923.)

Occupational therapy will surely have its place in treatment, and an important place it may be. The active and the paralyzed muscles must be studied and planned for.

Attention to these common matters will often result in great comfort and always in the gratification of the helpless and hopeless invalid.

CHAPTER V

FRACTURES OF THE RIBS

Anatomy.—Palpation of most of the ribs is comparatively easy. The upper seven ribs on each side articulate with the sternum. The eighth, ninth, and tenth ribs are connected by the costal cartilages anteriorly, but the eleventh and twelfth ribs have no anterior attachment. These lowest ribs are, therefore, less liable to fracture. The first two ribs are somewhat protected by the clavicle from direct violence, although great depression of the shoulder may bring the clavicle to bear directly upon the first ribs, and this may be a cause of fracture. The ribs are so elastic in childhood that fracture then is extremely rare. Direct violence is the common cause of fracture.

Symptoms.—In partial fractures there may be no symptoms. Upon forcible expiration (as in sneezing, coughing, laughing, crying, or in breathing hard) pain may be felt at the seat of fracture. So definite is the pain that the patient may be able to place his finger accurately upon the seat of fracture.

Crepitus is often felt by the patient when moving or making an expulsive effort. Crepitus is elicited for the examiner by firmly placing the palm of the hand flat upon the chest at the supposed seat of fracture when the patient coughs. If crepitus is present at the time of coughing, a slight crunch or click will be felt and sometimes heard. The stethoscope placed near the supposed fracture will often assist in detecting the crepitus. The ribs should be palpated systematically, and the chest slightly compressed between the two open hands anteroposteriorly and laterally to detect crepitus. The natural inclination of the ribs should be borne in mind during palpation. Respiration will be short and catchy, and accompanied by a characteristic grunt.

The attitude and movements of the patient are very deliberate, guarded, stiff, and in severe cases suggest the movements of a child with acute caries of the dorsal spine. There may be a slight cough.

Complications and Sequelæ of Fracture of a Rib.—Ileus may result. Injury to the pleura and lung not uncommonly occurs. Its existence is manifested by cough, bloody expectoration, and emphysema. Emphysema may extend over the whole chest and up over the neck and face (Fig. 187), and even over most of the body. Emphysema unassociated with a wound of the superficial soft parts is of little importance.

Emphysema locally near a fracture of a rib originates from the communication that is traumatically made between the parenchyma of the lung and the subcutaneous tissues. Emphysema that is extensive probably starts with smaller or larger injuries to the lung itself independently, perhaps,

of a fracture of a rib. The bronchial air escapes into the loose peribronchial tissues and, by passing along lines of least resistance, gains entrance to the

Fig. 187.—Emphysema following fracture of the ribs on the right side. Note the puffiness of the face—the eyes almost closed (Warren).

Fig. 188.—Fracture of ribs. Emphysema general. Adhesive plaster swathe about chest. Note closure of right eye and puffiness of face and hands (Monks).

mediastinum, and thence along fascial planes, to the subcutaneous tissues. The closed pleural sacs are not involved and there is, therefore, an infrequency of pneumothorax (Meyer and Lucke).

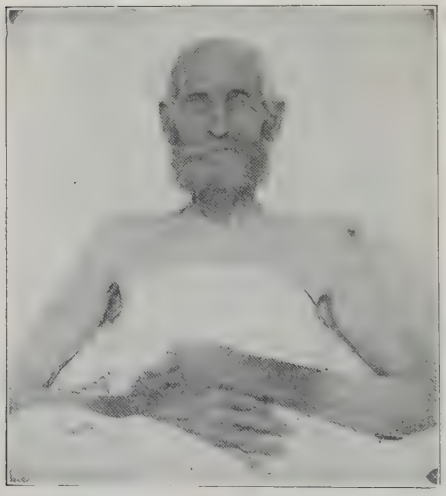


Fig. 189.—Same case as Fig. 188. Emphysema entirely disappeared. Contrast the two appearances (Monks).

Pneumothorax may be present. If the physical signs of pneumothorax are associated with only moderate dyspnea, very careful immobilization of the fracture should be attempted and morphin administered. If the dyspnea becomes alarming, aspiration of the chest to remove the air from the pneumothorax should be practised. Injury to the heart and pericardium and hemorrhage from an intercostal artery are unusual. A dry pleurisy, disappearing rapidly, localized at the seat of fracture, is quite commonly detected by the stethoscope. The relations of a rib to the pleura and intercostal vessels are important in this connection (Fig. 190).

Treatment.—The complications must be attended to according to medical principles. A cough mixture, if necessary, containing morphin is a great

help during the first week. It is often difficult to reduce a fracture of a rib and to hold it reduced. The deformity and loss of function consequent upon the union of a fractured rib in malposition are fortunately not very great. However, the relief of the patient upon the partial immobilization of the fracture is considerable. By pressure of the hand the ribs may be steadied and the fragments brought into excellent apposition, and by a pad held in place by a swathe of adhesive plaster this apposition can be maintained. The application of an adhesive plaster swathe is attended with much comfort and is easily accomplished. The swathe should be broad enough to cover the chest 6 inches on either side of the fracture of the rib, and long enough to extend three-fourths of the way around the body. It is applied as follows: One end is fixed to the trunk of the patient at the spine, the

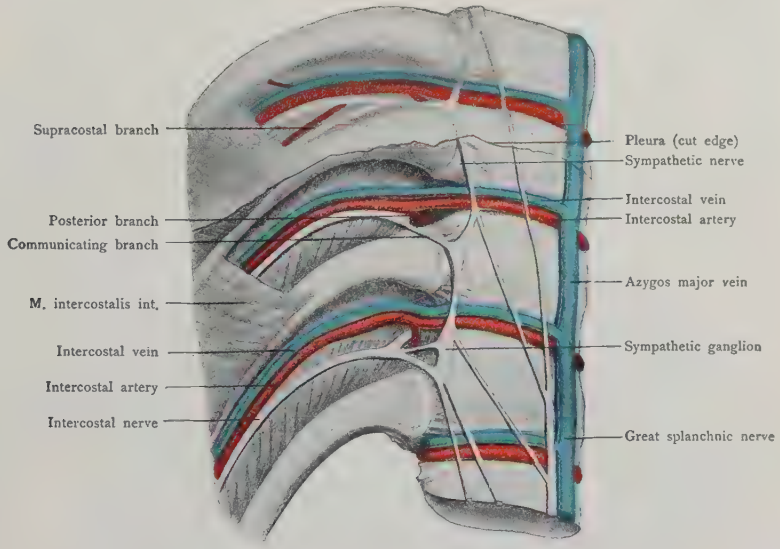


Fig. 190.—The right intercostal region. In the upper of the three intercostal spaces represented the pleura is still intact; in the second it has been removed; in the third the internal intercostal muscle as well as the pleura has been taken away. Fracture of a rib may cause serious injury to pleura, vessel, or nerve (Schultze and Stewart).

patient standing erect with the hands upon the top of the head (Fig. 191). The surgeon, taking the loose end of the swathe and holding it taut, walks around the patient, applying the swathe to the patient's chest while the patient, standing, turns slowly as if on a pivot toward the surgeon (Fig. 192). It is important to avoid covering the constantly moving abdomen by the swathe. A swathe made of several long strips of adhesive plaster, each strip being 4 inches wide, imbricated in the application, will often prove more comfortable than a single swathe. The comfort attending the wearing of such a swathe speaks much for its efficacy.

Operative Treatment.—If there is great displacement that is irreducible by pressure, an incision and elevation of the parts and immobilization by suture are to be considered.

Fig. 191.—Fracture of the ribs. Starting the application of the adhesive plaster swathe to encircle the trunk. Fixation of initial end of the swathe at the spine. Notice that the swathe is held taut as it is applied.

Fig. 192.—Fracture of the ribs. Finishing the application of the adhesive plaster swathe to the trunk.

After-treatment.—The upright position will give the most comfort. The swathe should be changed at least once each week. It will require about

three weeks for the union to become firm. A cotton swathe may be worn during the third and fourth weeks in place of the adhesive plaster swathe. At the end of four weeks all swathes may be removed. Massage to the seat of fracture will, after the first week, hasten healing and a restoration of the parts to a normal condition. If there have been any pleural or lung complications, great precaution should be exercised in the after-care. The avoidance of exposure to cold and of great bodily exertion for a period of two months or more following recovery from the complication is necessary.

Other injuries, such as strains of the shoulder and back, are likely to appear some days after the acute symptoms of a fracture of the rib have subsided. It is well to examine the patient with a fractured rib for associated injuries. These associated sprains often cause considerable anxiety to the patient for fear that more serious trouble than a broken rib exists. In pa-

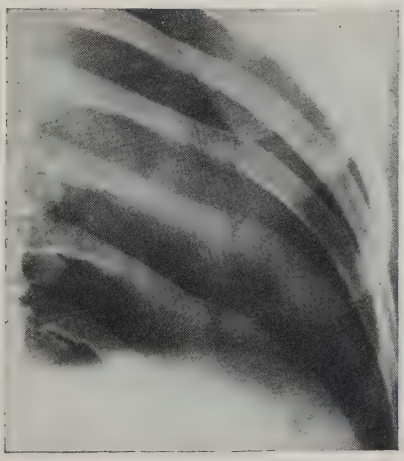


Fig. 193.—Fracture of ribs (Healey).

Fig. 194.—Avulsion fracture of transverse processes of lumbar vertebræ without visceral lesions. Same case as Fig. 193 (Healey).

tients over fifty years old "neuralgic pain" at the seat of fracture will sometimes persist for several weeks after the fracture is firmly united. This may be relieved by application of moist heat to the affected part and by counter-irritation of a more vigorous kind. The use of tincture of iodin and blisters is often a great help. In the aged the shock of the injury is considerable. In feeble persons a pleurisy or pneumonia may prove fatal.

Treatment directed to the removal of the *emphysema* is ordinarily unnecessary. The emphysema usually disappears in a week or ten days. If the distention of the subcutaneous tissues is extremely painful and increases very rapidly, it may be wise to make several antiseptic incisions over them, allowing the air to escape, to relieve the tension of the skin.

CHAPTER VI

FRACTURES OF THE STERNUM

It is difficult to palpate the sternum accurately. The episternal notch is felt between the two inner ends of the clavicles. The junction between the first and second portions of the sternum is distinctly felt opposite the second costal cartilage as a ridge. The common site of fracture is shown in Fig. 195. The fracture that is usually due to direct violence is seated in the upper part of the second portion of the sternum near the junction of

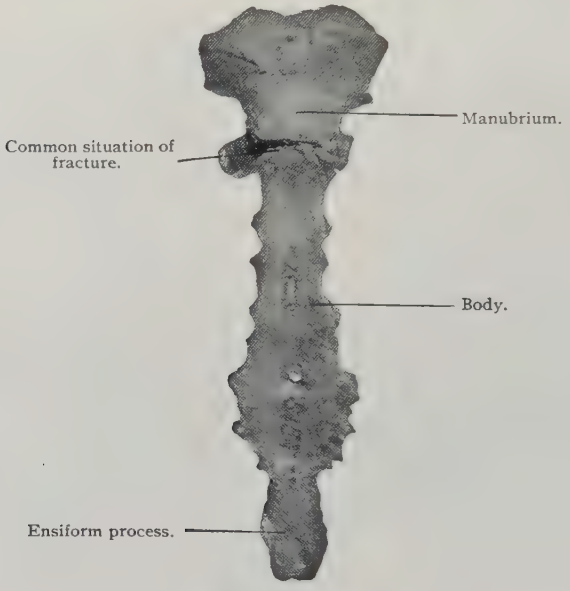


Fig. 195.—Sternum of an adult. Note separation at junction of manubrium and body.

the first and second portions. The upper fragment is displaced backward behind the upper end of the lower fragment. The displacement, the abnormal mobility, and possibly crepitus after each respiratory act or upon coughing, the localized area of pain, all increased by pressure and deep inspiration, help to make the diagnosis certain. Percussion may discover dulness if there is a hematoma of the anterior mediastinum.

The patient stands in a characteristic fashion with body bent forward. It is almost impossible to distinguish a dislocation at the junction of the first and second portions of the sternum from a fracture within the first portion of the sternum. Careful palpation and consideration for the age of the patient together with Roentgen examination will enable one to decide. The ossification of the sternum takes place irregularly. At the twenty-fifth

year all parts are usually ossified. The lesions sometimes associated with fracture of the sternum—viz., fracture of the ribs and injury to the lungs and heart—are usually so severe that the patient does not recover from them. If no complicating lesions are present, the outlook for recovery is favorable. It is very important to examine the anterior thorax after falls upon the head and shoulders.

Treatment of Fracture of the Sternum.—Spontaneous reduction has occurred in several instances upon coughing or sneezing. If the patient is placed upon his back with his head extended over the end of the table and the arms are then raised above the head and rotated outward slowly and forcibly, the deformity is sometimes reduced. The body of the patient, meanwhile, is steadied by an assistant. Traction and countertraction are thus made upon the two fragments (Fig. 196). An adhesive plaster swathe should be placed about the chest high up, and held firmly in position by straps across the shoulders. Union takes place in from three to four weeks.

Fig. 196.—Position in, and method of reduction of, fracture of the sternum. Notice positions of hands of surgeon and assistant.

The fracture is solid in from six to eight weeks. After resting on the back in bed for three weeks the patient may be allowed to be up occasionally with care to avoid violent exertion. For the greatest precaution a Taylor steel back-brace, with apron and head support, should be used for two months after the patient is up and about. This brace is similar to that used in high dorsal caries of the spine.

Operative Treatment.—Incision and elevation of the depressed fragment have been done successfully, and are to be considered in difficult cases after the shock of the original injury has passed away. Cyanosis and dyspnea may be in part dependent upon the displacement of the sternal fragments. Relief from these symptoms is often immediate upon the correction of the deformity. If there are alarming symptoms immediately following the injury operative attempts at relief of the deformity are justifiable and wise.

CHAPTER VII

FRACTURES OF THE PELVIS

Anatomy—Examination—Fracture of the ilium—Fracture of the pubic portion—Treatment—Use of swathe in suspending pelvis—Visceral lesions—Rupture of urethra—Rupture of urinary bladder—Prognosis—External peroneal injury—After-care of fracture of pelvis—Fracture of the floor of acetabulum—Prognosis—The Balkan frame, U. S. Army type.

The pelvic bones are generally considered inaccessible (Fig. 197); but with a systematic anatomical examination, especially if assisted by digital examination by the rectum and the vagina, practically all parts of the pelvic bones may be palpated. Roentgenological examination will accurately

Fig. 197.—Normal pelvis. Note relations of pelvic ring.

locate a fracture. Movement of the hip will often determine the integrity of the acetabulum, which is, of course, most difficult to palpate even posteriorly by the rectum. Fractures of the pelvis are occasioned by great violence. Fracture occurs most often in falls from a height, and is due to the sudden pressure upon the pelvis through the thighs and hips or through the spinal column upon the sacrum and sacro-iliac synchondroses. Antero-posterior pressure and lateral compression, as in the car-coupling accident, are common causes of fracture. From a clinical standpoint these fractures

fall into two groups—fractures of the individual bones without injury to viscera, and fractures at different points in the pelvic ring usually associated with visceral lesions.

Fractures of the sacrum, the coccyx, the symphysis pubis, and the ischium are extremely rare.

Examination.—The examination should be systematically made in order to cover thoroughly the irregular bones of the pelvis. The ilium of each side should be palpated to detect a fracture of either crest. Then the two ilia should be crowded gently but firmly together in order to determine crepitus due to the presence of fracture elsewhere. Then the pubis and ischium upon the two sides are to be palpated externally as far as is practicable. Finally a careful rectal and vaginal examination should be made

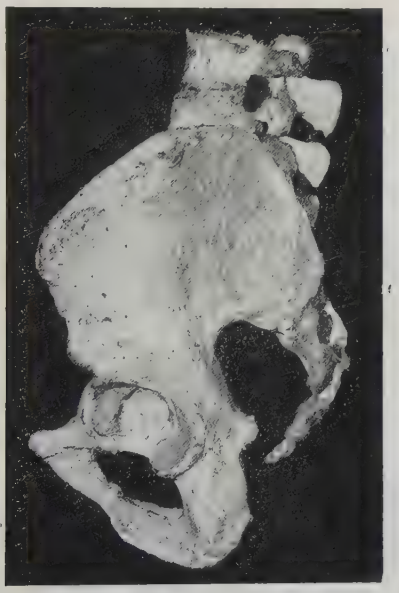


Fig. 198.—Lateral view of adult pelvis.

of the pelvic bones. The rectal examination will help to determine actual damage to the rectal wall and it may assist in determining impending damage from projecting sharp spicules of bone. The patient should be catheterized to assist in determining the presence of an injury to the urinary tract.

Fracture of the Ilium (Fig. 199).—This fracture is not unusual. The crest of the ilium is commonly broken. Pain, swelling, crepitus, and abnormal mobility may be present. Localized tenderness at the seat of fracture may be the only sign present. Crepitus, absent at first, may be elicited several days after the injury. There is comparatively little displacement. Union occurs in from three and half to four weeks. The patient ordinarily only requires restraint in bed. The outlook is for a good recovery unless there is a visceral lesion. Slight deformity may be noticeable upon full recovery (Fig. 200).

Fracture of the pubic portion of the ring of the pelvis is the commonest fracture. It is usually associated with other fractures or separations of

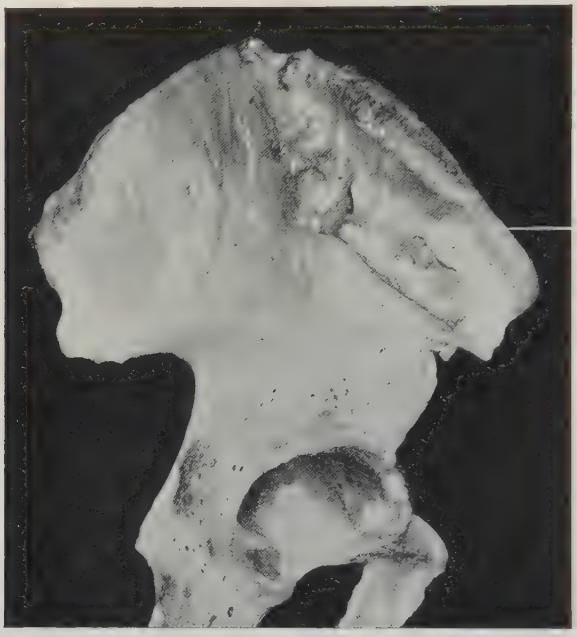


Fig. 199.—Fracture of crest of ilium (Warren Museum, Specimen 5938).

bony surfaces of the pelvis. Fractures of the rami may be suspected if there is local tenderness associated with muscle spasm of the adductor muscle

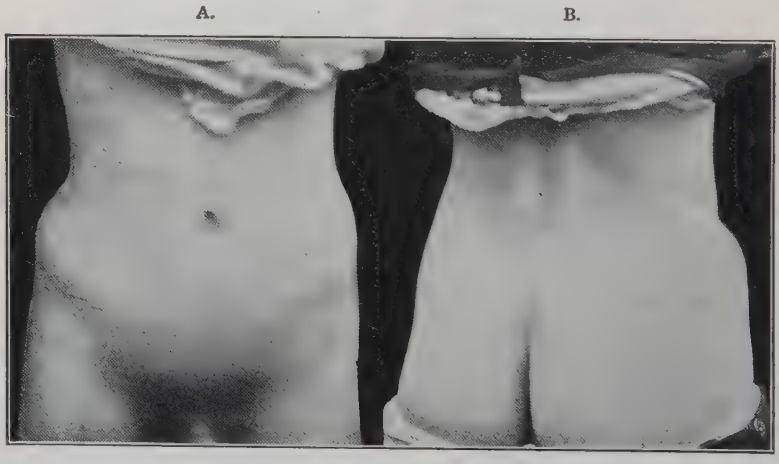


Fig. 200.—Fracture of the crest of the right ilium: A, Deformity due to inward displacement of fractured bone. B, Posterior lateral view (Porter).

group. Injury to the urethra is not uncommon in this fracture (Figs. 201, 202).

Treatment.—A snugly fitting swathe encircling the pelvis should be applied to assist in immobilizing the fracture. If the fracture is of the ilium alone, the swathe should be applied loosely enough to avoid displacing the

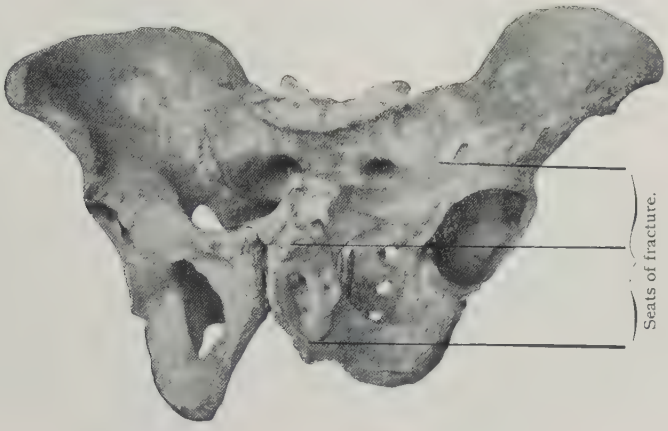


Fig. 201.—Fracture of rami of pubes; fracture and separation at sacro-iliac synchondrosis; much displacement; bony union (Warren Museum).

fragment of the crest inward, thus causing permanent deformity (see Fig. 200). Jopson has utilized a simple swathe under the pelvis at an appropriate

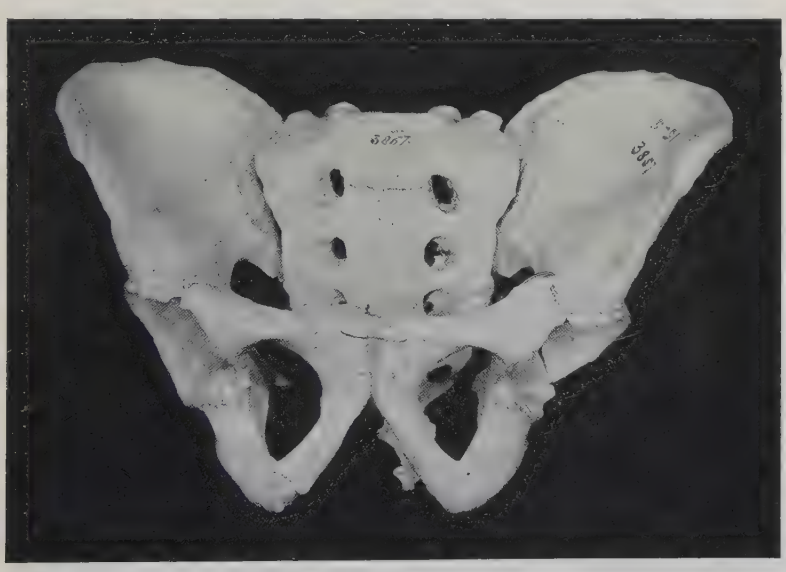


Fig. 202.—Fractured pelvis: On the right, fracture across pubes and ischium; on the left, fracture involving acetabulum and sacrosciatic notch (Warren Museum, Specimen 3857).

level which is suspended or slung to an overhead horizontal bar. The pelvis is thus steadier. Lateral pressure and suspension just clear of the bed secures comparative comfort for the patient.

The Use of the Swathe in Suspending the Injured Pelvis.—The swathe about the pelvis may be applied and adjusted so as to exert a positively

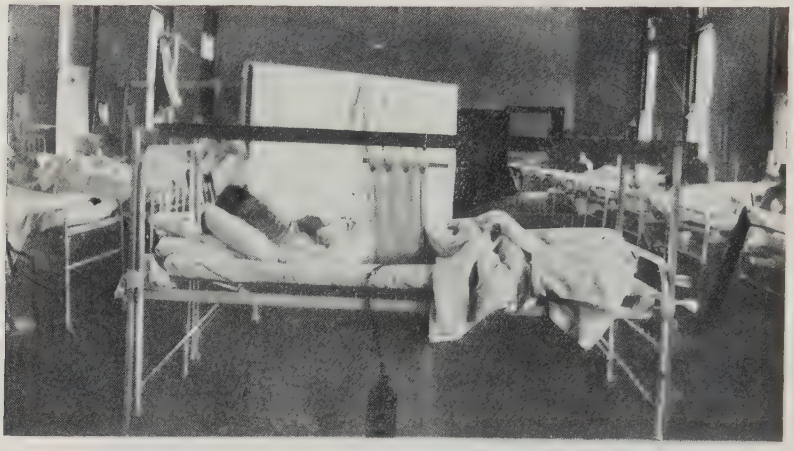


Fig. 203.—Fracture of the pelvis. Suspension of pelvis to secure coaptation of fragments, ease in motion, and comfort to patient lying in bed (John H. Jopson, Annals of Surgery).

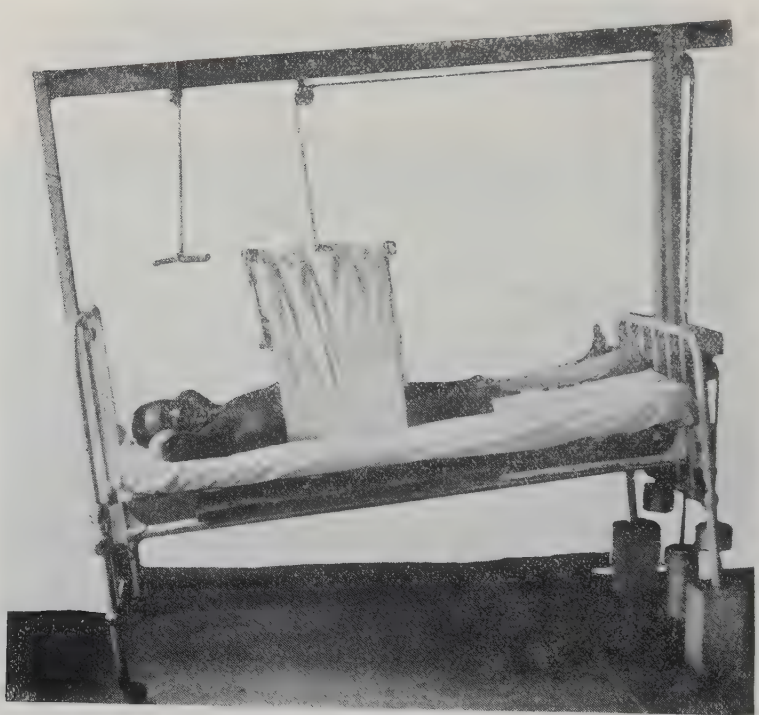


Fig. 204.—Overhead pelvic suspension hammock, used in certain fractures of the pelvis. See diagram, Fig. 206 (Conwell).

definite effect upon the fracture under treatment and not be a mere passive inactive sling. In separations of the sacro-iliac joint a swathe may be so

misapplied as to actually open the joint surfaces wider. The swathe should be applied so as to crowd the soft parts, the skin, subcutaneous

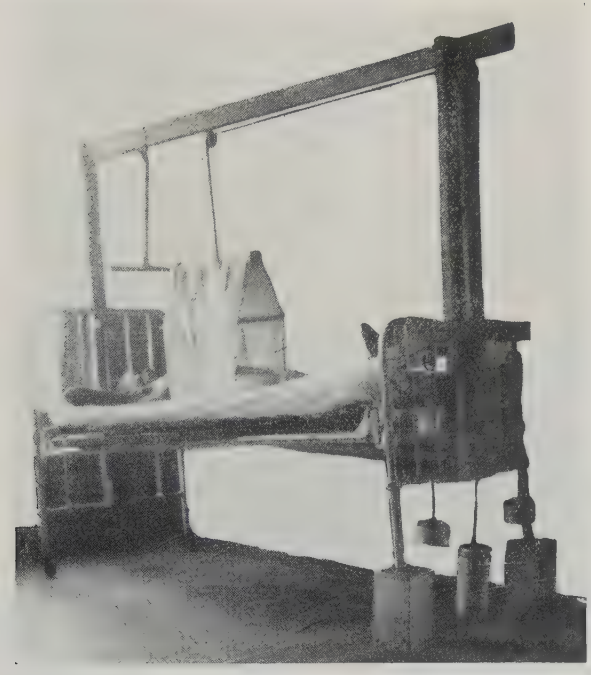


Fig. 205.—Overhead pelvic suspension hammock. Note wooden spreader in use. See diagram, Fig. 206 (Conwell).

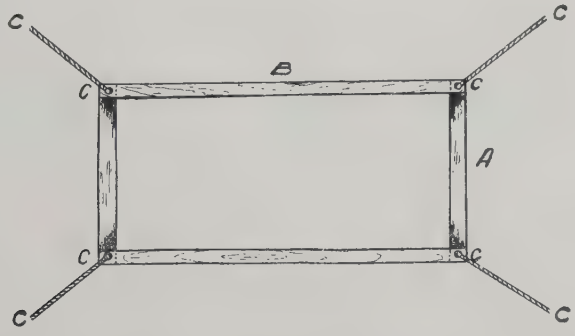


Fig. 206.—Wooden spreader used for overhead pelvic suspension hammock: *A*, The cross-piece of wood of the frame, which is ¾ inch in thickness to 1½ inches wide. This piece is the exact width of each individual patient's pelvis. *B*, The same size piece, which is the exact length of the canvas hammock. *C*, Small ropes which are attached to each corner of the wooden spreader. The ropes are attached to the cross-piece, *R*, by the ropes, as shown in pelvic suspension frame, and allows spreader to be lowered or raised to any height. (H. Earle Conwell.)

fat, and two great glutei of the two buttocks together instead of apart. Thus the tendency will be to hold the sacro-iliac joint surfaces close together (Smith-Petersen.).

In fractures of the rami of the pubes it may be possible by the combination of the use of a swathe, abduction, and traction to affect the site of the fracture favorably.

In other words, it is important that the surgeon should regard and employ the sling swathe, especially when it is used with other means, such as traction and position, as an active agent in the treatment and not merely as a convenient means for comfort (Smith-Petersen).

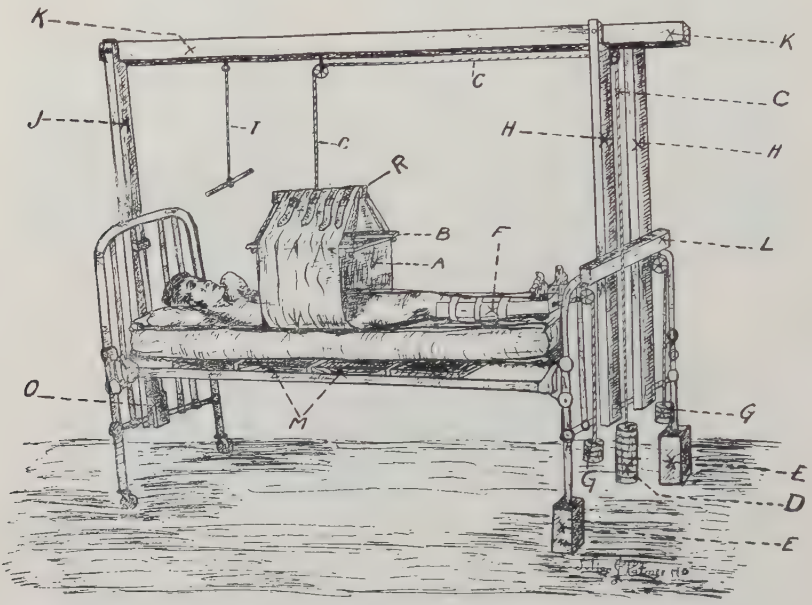


Fig. 207.—Overhead pelvic suspension frame with hammock and wooden spreader: *A*, Suspension hammock. *B*, Wooden spreader, which prevents overlapping of the pelvic fragments from the side pressure by the hammock. This spreader is made the exact width of the individual patient and the whole length of the hammock, which is usually about 2½ feet long. The spreader is made of material of about ¾ inch thick and 1½ inches wide. *C*, Main pull, which is usually about 25 to 30 pounds. *D*, Weight applied. This weight here is one-quarter less than the main pull on hammock. *E*, Elevation of bed on 12-inch blocks. *F*, Adhesive traction applied on legs below knee, showing abduction by pull. *G*, The weights applied here are ranging from 4 to 6 pounds. This abduction can be applied according to which leg you wish to pull most, and also cause abduction of both legs, which is very essential in pelvic fractures. *H*, The two foot uprights which are attached to bed. *I*, Pulley allowing patient to lift himself in bed. *J*, Head upright, which is also attached to bed. *K*, Main longitudinal bar which bears main weight. *L*, Cross-piece holding pulleys for traction of feet. *M*, Wooden boards underneath mattress to prevent sagging of bed. *O*. Main assembly joint of all the wooden pieces to bed. *R*, Wooden bar 2 by 2 inches square and length of hammock where main pull is applied. (H. Earle Conwell.)

All uncomplicated fractures of the pelvis are to be treated by hammock suspension and by traction.

The lateral drag of the hammock may at times cause an overlapping of fragments unless the effect of the hammock is offset by the intelligent use of a spreader to the suspended hammock—raising or lowering the spreader will control the lateral pressure (Nolan and Conwell).

Difficulties attending the care of a bed-ridden patient are also thus minimized (Fig. 203). The patient should in all cases, except simple fractures of

the crest of the ilium, be placed upon a properly fitting Bradford frame. Upon this frame, and in no other way, can the patient be comfortably nursed. The bed-pan can be adjusted with ease and without disturbing the fracture. The bed can be most readily changed and the patient kept clean and comfortable. If it is probable that movements of the hip-joints cause motion at the seat of the fracture, the thighs should be fixed so as to immobilize these joints. The long outside wooden splint extending from the axilla to below the heel and attached at its foot end to a slat at right angles to the long upright—a T-splint—is the simplest means of securing this immobilization. If the patient is on a Bradford frame, sufficient immobilization is easily accomplished by encircling the thighs separately or together and the frame with a towel swathe. Extension of the limbs by weight and pulley may be

Fig. 208—Median section of male pelvis. Note the close relations of bladder and urethra to the symphysis pubis. Injury to the symphysis and descending rami of the pubes can readily damage the adjacent urethra: *R*, Rectum; *Pr*, prostate; *B*, bladder; *S*, symphysis pubis; *Sc*, scrotum; *P*, penis.

needed in addition in certain cases to secure immobilization of the fracture. Wiring or suture of the fractured bones may be entertained and practised. Wiring is indicated if comminution or displacement of fragments is great.

Visceral Lesions.—Associated with fractures of the pelvis there may be lesions of important viscera. These visceral lesions render fractures of the pelvis of the very greatest seriousness. The trauma causing the fracture may at the same time occasion a rupture of the kidney. The bladder, urethra, or bowel may also be ruptured. The shock associated with a fracture of the pelvis is great. If there is a visceral lesion, the primary and secondary shock will be very great.

Rupture of the Urethra.—This is sometimes associated with fracture of the pelvis (Fig. 208). It may be due to the original trauma, as a fall or

blow on the perineum, or it may be caused by bony fragments lacerating the urethra, or by a simple separation of the symphysis pubis. Pain at the

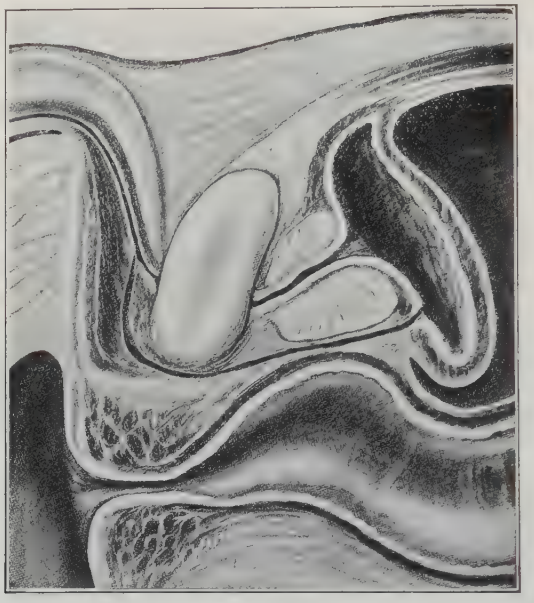


Fig. 209.—Fracture of the pelvis. Rupture of urethra. Note the displaced ends of the urethra. Note the false passage to bladder (Cabot).

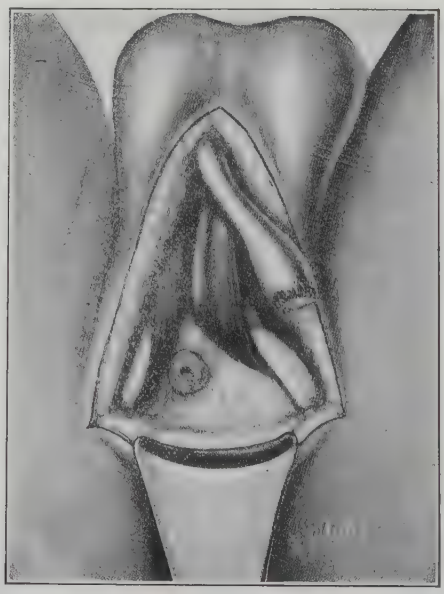


Fig. 210.—Fracture of the pelvis. Rupture of urethra. Note the possible mobilization of the urethra (Cabot).

seat of the lesion, pain upon pressure in the perineum, retention of urine, urethral hemorrhage, swelling in the perineum, usually exist. Under these

circumstances perineal section is indicated in order to drain the wounded area and the bladder. After finding the urethra by perineal section a catheter passed through the penile urethra is introduced further into the bladder.

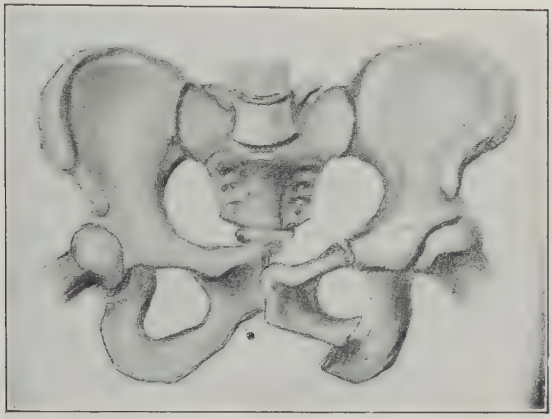


Fig. 211.—Fracture of the pelvis. Rupture of urethra. Note displacement of fractured bone with separation at the symphysis (Cabot).

If a catheter can be passed to the bladder and the local swelling does not increase, permanent catheterization is indicated. The patient should, however, be watched carefully for the signs of extravasation of urine. If at any time the catheter cannot be passed, operation should be done at once, as in the first instance.

If the urethral rupture is caused from above, the inferior surface of the canal may be intact. If so, the passage of the catheter (if difficult) may be facilitated by depressing the instrument slightly, hugging the inferior wall of the urethra.

If the urethra in its perineal or scrotal portions is destroyed by a fracture of the pelvis, if there is an actual loss of substance, Cabot has shown that the principle of mobilizing the urethra may be applied with good results in restoring the canal. The mobilization may be carried farther than has been hitherto thought possible. Figures 209 to 212 illustrate a case in point. In all plastic work tension of parts is to be avoided. This demonstration by Cabot of the possibility of great mobilization of the urethra makes a suture of the urethra without destructive tension possibly successful.

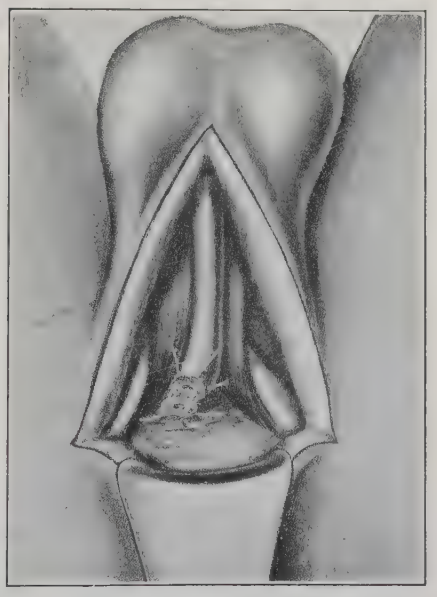


Fig. 212.—Fracture of the pelvis. Rupture of urethra. Note sutures placed to unite much mobilized urethra (Cabot).

Rupture of the Urinary Bladder.—In every fracture of the pelvic bones the integrity of the urinary bladder should be determined by careful examination. Rupture of the bladder will be either extra- or intraperitoneal. In the intraperitoneal rupture of the bladder the urine escapes from the bladder into the peritoneal cavity—in the extraperitoneal rupture the urine extravasates throughout the pelvic tissues. When the bladder is empty, it is low down in the pelvis and can be injured only by a fracture of the pelvis. The rupture of the bladder due to fracture of the pelvis is usually extraperitoneal and it is situated on its anterior surface.

On account of the fracture the patient cannot walk. Rupture of the bladder itself might occasion inability to walk, at least any long distance. There is great hypogastric pain, frequent desire to micturate, and inability to pass urine. A few drops of bloody fluid escape from the meatus. Dulness may be present in the lower abdomen and loins. Soon after the accident, if not immediately, there is great prostration. Evidences of shock are seen in the pallor of the face, the anxious expression, the feeble pulse, the cold, clammy skin, and the feeble voice. The abdomen becomes distended, the temperature rises, and delirium, coma, and death follow with certainty unless operative interference has relieved the condition at a very early hour after the accident. The patient dies from shock, hemorrhage, or septic peritonitis.

If the patient is seen soon after the accident, before untoward symptoms have appeared, and has not micturated for some little time, he should be catheterized. An empty bladder will be found or a small amount of bloody fluid will be withdrawn, which rather confirms the other evidences of ruptured bladder. If there is doubt as to the rupture of the bladder, the symptoms should be watched and a cystoscopic examination should be made at once by means of a small observative cystoscope. The symptoms of rupture may be masked or delayed by the associated lesions. The urine may be tinged with blood because of a contusion of the bladder. The catheter may be passed through the bladder wall, and be felt to enter the abdominal cavity, evacuating bloody fluid. All fluid having been removed from the bladder, if a measured amount of sterile water is injected into it, and all that was injected does not return, presumption of rupture of the bladder is very great. The pelvic cavity, on the other hand, may be inadvertently catheterized and the same amount of urine or water gotten back that is put in (Müller). Under such circumstances the dull area in the groins and lower abdomen of extraperitoneal rupture will be increased. Upon injecting fluid through a catheter passing through the urethra, to be sure that the fluid enters the bladder and remains in the unruptured bladder, a suprapubic bladder tumor should appear as the fluid enters the bladder (Ashhurst).

If a rupture of the bladder is found, whether intra- or extraperitoneal, an immediate suprapubic cystotomy should be done, and drainage instituted by this route.

If the rupture is intraperitoneal, there will be little need of flushing the abdomen. Whether the rupture is within or outside the peritoneum it will

ordinarily be unwise to suture the rent in the bladder wall. If it can be accomplished quickly, without delay, it is good surgery to suture it.

A ½-inch tube of rubber lying in the bladder through the suprapubic wound will adequately drain the bladder of all urine. The traumatic rupture wound will heal spontaneously. In neglected cases Fuller emphasizes the importance of dependent drainage of the extravesical spaces. Drainage-tubes should be placed to lie beneath the pubic bones and emerge in the perineum. This burrowing of pus and deep pelvic cellulitis, resulting in sloughs and a general sepsis, will be ordinarily prevented by the initial and early suprapubic drainage.

The surgeon should err in leaving the suprapubic drain in place too long rather than too short a time. The suprapubic drain is removed when the bladder rupture wound has healed. This may be determined by palpation of the interior of the bladder by a gloved finger. On removing the suprapubic wound drain a catheter is introduced through the penile urethra into the bladder.

A suprapubic wound will close, if urethral drainage is employed, in about ten days after removal of the suprapubic drainage.

Prognosis.—A guarded prognosis should always be given in any case of fracture of the pelvis. Fractures of the iliac crest ordinarily recover in a few weeks. In fractures complicated by rupture of the bladder or bowel the prognosis is extremely grave.

External Peroneal Nerve Injury—Foot-drop.—A complication of fracture of the pelvis which G. G. Davis has observed and to which he has directed especial attention. The facts stated here are from the experience of Davis: The complication occurs in about 2 per cent. of pelvic fractures. The symptoms of foot-drop appear immediately following the injury. The trauma to the nerve is in the origin of the lumbosacral cord as it lies at the pelvic brim. The likelihood of improvement of the foot-drop is not great.

While the patient is in bed for treatment of the fracture, massage and electrical treatment to the muscle involved is indicated. Support should be given to the foot-drop by suitable splint with stop joint at the ankle. After a year, if the nerve shows continued symptoms of complete division or permanent damage, a transplantation of the peroneus longus into the anterior tibial tendon by the Mayer technic is advisable.

In the case of M. V. C. recorded by Davis (see Figs. 214–216) the following neurological report was made by P. Bassoe:

First neurological examination, August, 1924: He presents symptoms of a lesion of the left external popliteal nerve, evidently produced in connection with a fracture of the pelvis. It is possible that he has a high bifurcation of the sciatic nerve or that the injury to the posterior tibial division was less severe. There is marked atrophy of the left calf and slight of the left thigh, the latter probably due to disuse. He is able to extend the small toes of the left foot a little, not the big toe, and not the ankle. Plantar flexion is good. The strength at the knee and hip is good. He can evert the left foot a little.

The plantar, ankle, and knee reflexes are normal on both sides. The paralyzed muscles, namely, the extensor group of the left foot, with the exception of part of the peronei, give typical reaction of degeneration. There is very little disturbance of sensation, consisting of impairment of pain and temperature sensation of the outside of the left foot and the lower part of the external aspect of the left leg. Tactile sensation is preserved.

The distribution of the motor and sensory symptoms indicates a lesion of the nerve trunk in its course through the pelvis rather than of the roots higher up. The nerve is probably not severed, at least not completely so. The prognosis nevertheless is not favorable as to any great further return of power in the paralyzed muscles. There may be some further improvement for a year or a year and a half after the injury.

The second and last neurologic examination by the same observer, P. Bassoe, was made May 20, 1925, and was recorded as follows:

There was a previous examination on August 14, 1924. There is very little change in his condition. There is relatively less difference in the circumference of the affected calf and thigh, but the paralysis remains as before. The sensory disturbance is even more trivial than before. The mode of injury and the very slight sensory disturbance make it unlikely that the nerve was entirely severed. There may still be further spontaneous improvement.

The After-care of a Fractured Pelvis.—This is important. As a routine, these patients are kept in bed about six weeks. The hammock suspension is combined with bilateral leg traction with lower extremities moderately abducted.

Men should not be permitted to go back to work before the fifth or sixth month. If heavy work is attempted before this time, considerable pain is apt to develop, with lowering of morale and increased disability (Nolan and Conwell).

After the hammock is discarded he is kept in bed an additional week. A sacro-iliac belt is applied at this time. He is then up in a wheel-chair for two weeks. About the tenth week he is allowed up supported by crutches, bearing a little weight. The sacro-iliac belt is to be worn for at least four months.

FRACTURE OF THE FLOOR OF THE ACETABULUM

Following severe trauma to the outer surface of the hip from a fall from a height or from a direct blow on the great trochanter the neck of the femur may remain intact and the damage to the bone fall entirely on the acetabulum. The symptoms will depend in part upon whether the head of the bone has perforated the acetabulum or not.

The ordinary signs of fracture will be present. The trochanter will be nearer to the symphysis pubis than usual. A hematoma over the injured area within the pelvis may develop which can be palpated easily unless the peritoneum has been torn, in which case the blood may escape into the abdominal cavity and no hematoma will appear (Peet).

Fig. 213.—Fracture of the acetabulum. The head of the femur driven into the pelvis. Arrows point to the lines of the fracture (J. D. Adams).

Fig. 214.—Case M. V. C. Roentgen ray taken recently, September, 1925. Injury January, 1924. Note fracture of left ilium, rami of pubic bones (G. G. Davis).

Rectal and vaginal examinations may discover the bulge inward of the displaced pelvic wall.

Fig. 215.—Case M. V. C. Compare with Fig. 214. Injury January 21, 1924. Fracture of left ilium, left and right superior and left and right inferior rami of pubis. Note left foot-drop (G. G. Davis).

Fig. 216.—Case M. V. C. Same case standing as seen in Fig. 215. Note foot-drop on left side (G. G. Davis).

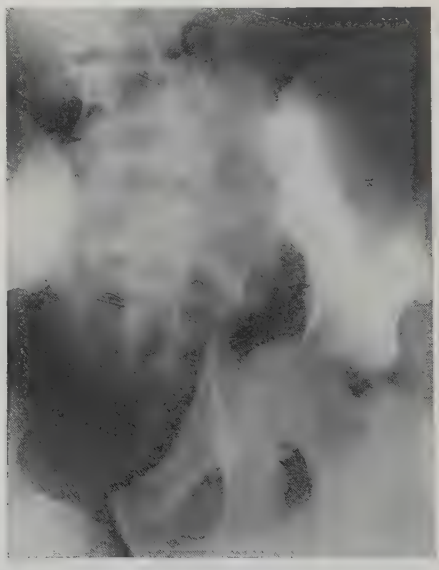


Fig. 217.—Case G. O. Injury December 16, 1923. Comminuted complete fracture of right ilium through acetabulum. Inward displacement of the head of the right femur. Transverse fracture of the superior and inferior rami of pubis. Dislocation of right ilium from the sacrum. Fracture of the transverse processes of the third, fourth, and fifth lumbar vertebræ. Dislocation of the symphysis pubis. Foot-drop, peroneal nerve injury (G. G. Davis).

An *x*-ray will always give indisputable evidence of the extent of the injury.

Injury to the obturator nerve, the large blood-vessels of the pelvis, the bladder, and the bowel may result in serious complications if the head of the femur perforates the acetabulum. The urethra has been torn in these pelvic fractures.

Fig. 218.—Perforating fracture of the acetabulum. Note stoving-in of the floor of the acetabulum, right side. Approximation of greater trochanter to ilium, posterior view. Sketch from Roentgen plate (Case I) (Skillern).

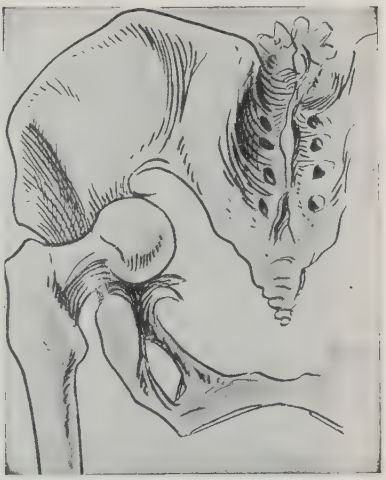


Fig. 219.—Perforating fracture of the acetabulum. Note head displaced into pelvic cavity. Juxtaposition of greater trochanter and ilium. Left side, posterior view. Sketch from Roentgen plate (Case II) (Skillern).

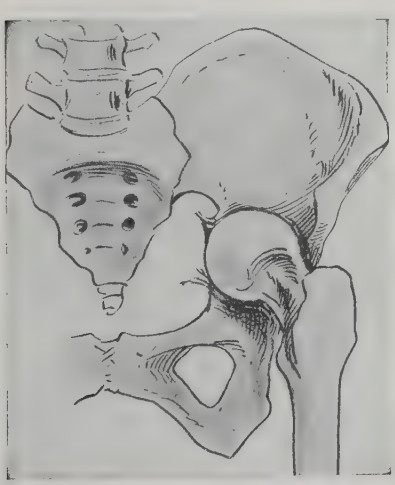


Fig. 220.—Perforating fracture of the acetabulum. Note head displaced into pelvic cavity. Juxtaposition of greater trochanter and ilium. Left side, anterior view. Sketch from Roentgen plate (Case III) (Skillern).

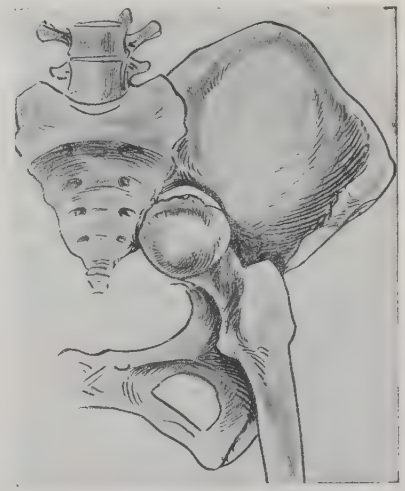


Fig. 221.—Perforating fracture of the acetabulum. Note head in contact with sacrum and entrance of greater trochanter into pelvic cavity. Left side, anterior view. Sketch from Roentgen plate (Case IV) (Skillern).

The reduction of the fracture by manipulation and traction may be very easy or most difficult.

If the head has not perforated the pelvis, lateral traction and longitudinal traction will be all that is necessary. If the head has perforated

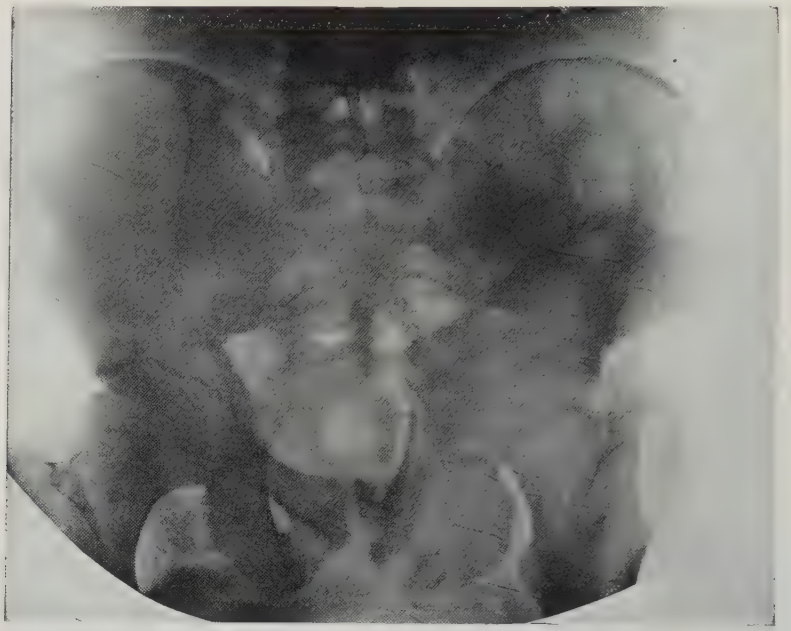


Fig. 222.—Fracture of the acetabulum. Femur intact. Head has not entered the pelvis. Note also fractures of symphysis pubis, rami of pubis and ischium (Arial George).

the pelvis, the head will have to be disengaged from the encircling fractured acetabulum before lateral traction will become effective. If the head is

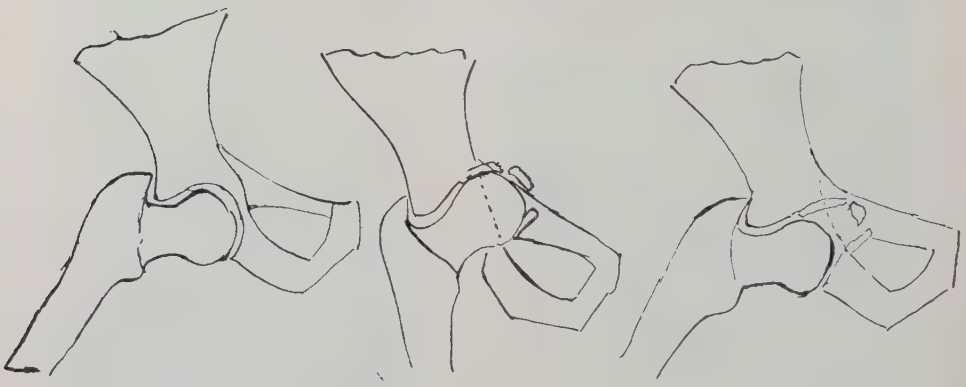


Fig. 223. Fig. 224. Fig. 225.

Fig. 223.—Contact of the trochanter and pelvis at the limit of normal abduction.
Fig. 224.—Contact of the trochanter and pelvis in central luxation restricting abduction by the abduction method.
Fig. 225.—Reduction of the displacement. (Whitman.)

not disengaged, the more powerful the traction, the greater will be the grip of the bony fragments around the head and neck.

Before any manipulation or vigorous examination is undertaken an *x*-ray is absolutely necessary to inform the surgeon as to the extent and lines of fracture and the exact position of the head of the femur.

Moreover, no vigorous treatment should be instituted ordinarily until the lapse of a few hours or days has proved that there is no important visceral injury.

The usual traction in the long axis of the limb and in slight abduction may succeed. If traction and countertraction with combinations of different positions of the thigh (in abduction and adduction) are unsuccessful,

Fig. 226.—Showing contact of the trochanter and acetabular rim limiting abduction in a fracture of the acetabulum (Whitman).

then an operative approach to the fractured acetabulum may be considered. The acetabular fragments may be elevated away from the neck of the bone, and then manipulation and traction may reduce the head. Resection of the head of the femur is rarely to be contemplated except in very long-standing injuries.

After reduction, immobilization by a plaster-of-Paris splint to the pelvis and lower extremity is necessary.

Prognosis.—If reduction is impossible and operative treatment for some reason is unwise, the prognosis will promise some limitation of motion, slight shortening, and considerable stiffness of the joint (Peet).

Subsequently, after all fixation apparatus is removed, manipulations, passive movements, if carefully made under an anesthetic, will result in loosening the stiff joint very considerably.

THE BALKAN FRAME, UNITED STATES ARMY TYPE

The introduction of the simplest form of overhead frame for the suspension of limbs, bodies, the pelvis, etc., is a very necessary thing. Such equipment is needed in every hospital. Provision for this need is met by Lieut.-Col. William L. Keller, M. D., whose carefully worked out description follows:

The advantages of the United States Army Balkan frame are its simplicity, cheapness, and ease of procurement. It will fit any bed, is easily

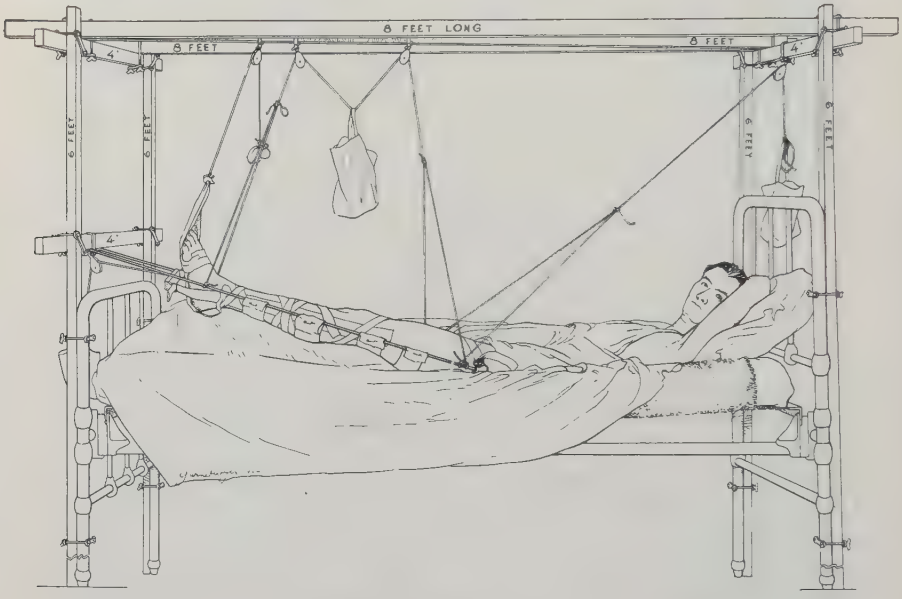


Fig. 227.—United States Army Balkan frame: Side view. (Keller.)

and quickly assembled and taken down, is light in weight, and requires the minimum of storage space. It is unexcelled as a suspension frame as it can be built out on either side to suspend either the upper or lower extremity, or both, at any angle of abduction required and also, at the same time, affords support for the pulley required for traction.

As shown in the accompanying illustrations, three different lengths of lumber are required, which can be procured at any lumber yard.

There are eight different metal parts making up the clamps, pulleys, and supports. All of these except one, as stated, are carried by any of the good-sized hardware stores. The U clamp used to support the pulley is made of strap iron, according to accompanying specifications and can be made by any blacksmith or the pulley may be tied to the frame with rope as a substitute.

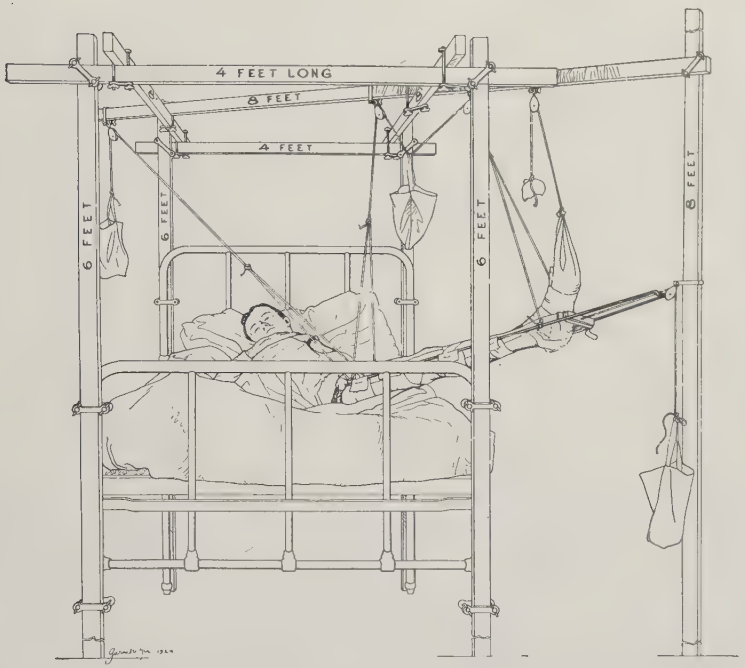


Fig. 228.—United States Army Balkan frame: Thigh in abduction. (Keller.)

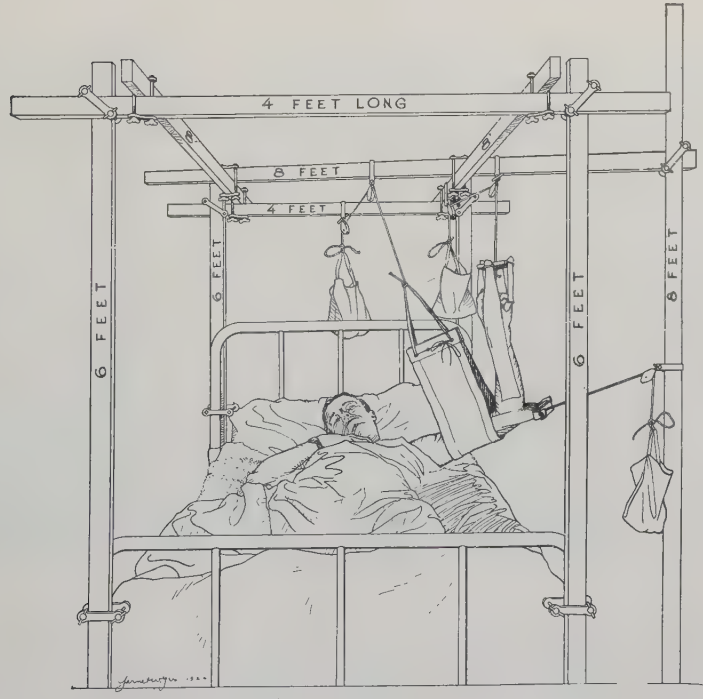
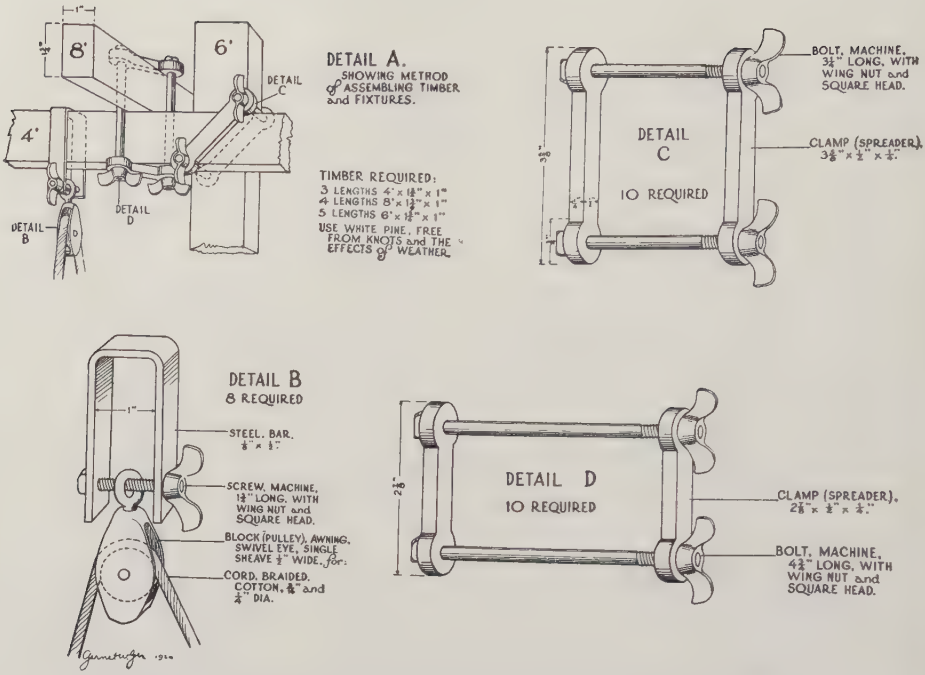


Fig. 229.—United States Army Balkan frame: Fracture of upper extremity. (Keller.)


8'
6'
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DETAIL C
DETAIL D
DETAIL B
DETAIL A.
SHOWING METROD of ASSEMBLING TIMBER and FIXTURES.
TIMBER REQUIRED:
3 LENGTHS 4' x 1½" x 1"
4 LENGTHS 8' x 1½" x 1"
5 LENGTHS 6' x 1½" x 1"
USE WHITE PINE, FREE FROM KNOTS and THE EFFECTS of WEATHER.
DETAIL C
10 REQUIRED
BOLT, MACHINE, 3½" LONG, WITH WING NUT and SQUARE HEAD.
CLAMP (SPREADER), 3⅜" x ½" x ¼"
DETAIL B
8 REQUIRED
STEEL, BAR, ⅜" x ½"
SCREW, MACHINE, 1½" LONG, WITH WING NUT and SQUARE HEAD.
BLOCK (PULLEY), AWNING, SWIVEL EYE, SINGLE SHEAVE ½" WIDE, for
CORD, BRAIDED, COTTON, ⅜" and ¼" DIA.
DETAIL D
10 REQUIRED
CLAMP (SPREADER), 2⅜" x ½" x ¼"
BOLT, MACHINE, 4½" LONG, WITH WING NUT and SQUARE HEAD.

Fig. 230.—United States Army Balkan frame: Metal parts and timber. (Keller.)

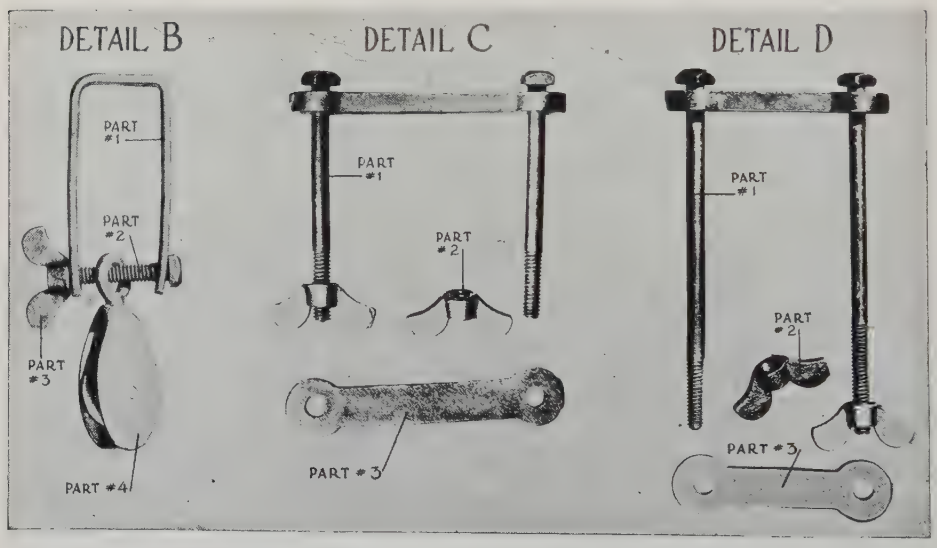


Fig. 231.—United States Army Balkan frame: Metal parts. (Keller.)

To carry out suspension traction treatment, the maximum weight ever needed for one extremity, femur, will be about 60 pounds; 30 to 40 pounds as traction, the rest of the weight being used for suspension. A convenient

type of weight is buck shot sewed in bags of bed-ticking or light canvas, weighing 1 to 5 pounds each.

Braided cotton rope $\frac{1}{8}$-inch for suspension of the lower extremity and suspension and traction in the upper is ideal. For traction in the lower extremity $\frac{1}{4}$-inch rope of the same type is preferable as the $\frac{1}{8}$-inch rope frays out and breaks over the pulley. Braided rope will not stretch, twisted will. Forty feet of $\frac{1}{8}$-inch rope will be required to suspend one femur and 3 feet of $\frac{1}{4}$-inch rope will be needed for traction.

Four bags made of light canvas or bed-ticking, sewed on three sides, with an open mouth and a piece of non-elastic webbing attached as a handle make excellent receptacles for weight, and are easily attached to the suspension and traction ropes.

TRADE NAMES OF MATERIAL USED IN UNITED STATES ARMY BALKAN FRAME

WOOD STRUTS, WHITE PINE OR SPRUCE (No. 1), FINISHED, FREE OF KNOTS, ETC., DIMENSIONS AND RETAIL PRICE AT LUMBER YARD. DIMENSIONS ARE FINISHED LUMBER

Detail A

3 pieces 1″ x 1¾″ x 4′ = 12 feet
4 pieces 1″ x 1¾″ x 8′ = 32 feet
5 pieces 1″ x 1¾″ x 6′ = 30 feet

74 feet @ .03½ cts. a ft. = $2.59

Detail B—(Pulley and Its Support)

Part No. 1 U clamp 2½″ sides 1″ wide of ¼″ x ½″ strap iron	$ .15	
Part No. 2 machine screw, square head 1½″ x ¼″	.01	
Part No. 3 wing nut ¼″	.02	
Part No. 4 pulley awning (with swivel)	.12	
(Eight required)	$ .30	= $2.40

Note.—U clamp has to be made. It and parts No. 2 and 3 can be dispensed with and pulley tied to frame with rope.

Detail C—(Clamp)

Part No. 1 machine bolt, square head 3¼″ x ¼″ (two required)	$ .02½	
Part No. 2 wing nut ¼″ (two required)	.04	
Part No. 3 clamp (spreader) 3⅝″ x ½″ x ¼″ (two required)	.10	
(Ten required)	$ .16½	= $1.65

Detail D—(Clamp)

Part No. 1 machine bolt, square head 4¾″ x ¼″ (two required)	$ .07	
Part No. 2 wing nut ¼″ (two required)	.04	
Part No. 3 clamp (spreader) 2⅞″ x ½″ x ¼″ (two required)	.10	
(Ten required)	$ .21	= $2.10

(Length measurement of machine bolts and screws includes head.)

Total cost $8.74

CHAPTER VIII

FRACTURES OF THE CLAVICLE AND SCAPULA

I. FRACTURES OF THE CLAVICLE

Anatomy—Symptoms in adult—Symptoms in childhood—Treatment—Barrel stave—Wooden cross—Modified Sayre—Treatment in childhood—Prognosis—Operative treatment—Ununited fracture.

Anatomy.—The upper surface of the clavicle is subcutaneous throughout its whole length (see Fig. 234). The acromioclavicular joint is at its outer end. The sternoclavicular joint is at its inner end. The clavicle lies in a muscular plane made up of the trapezius and sternocleidomastoid muscles above, and the deltoid, pectoralis major, and subclavius muscles below (see Fig. 234). It is important to recognize the situation and the direction

Fig. 232.—Upper surfaces of the right and left clavicles.

of the acromioclavicular joint in order to discriminate between a fracture of the outer end of the clavicle and one of the acromial process. It is likewise important intelligently to palpate the normal shoulder, to determine that the acromial process does not form the outer limit of the shoulder, but that it is formed by the greater tuberosity of the humerus.

Symptoms.—The common seat of fracture is in the middle third of the bone (Figs. 235–238 inclusive). The shoulder, having lost the support of the

clavicle, falls forward and drops inward (Figs. 241, 242), consequently the outer fragment which moves with the shoulder drops below the inner frag-

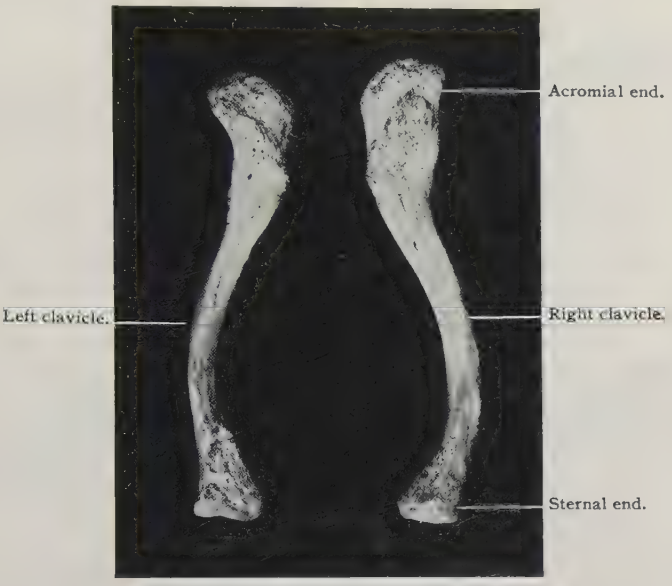


Fig. 233.—Under surfaces of the right and left clavicles.

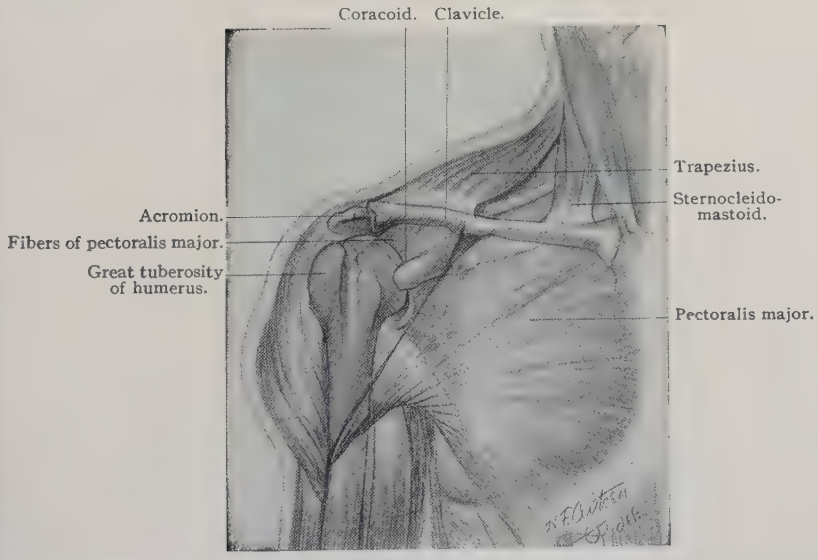


Fig. 234.—Muscles arising from and attached to the clavicle, showing the muscular plane in which the clavicle lies.

ment and overlaps it anteriorly or posteriorly. The inner fragment, having attached to it the sternocleidomastoid muscle and being comparatively free to move, is drawn slightly upward (Fig. 243). The attitude of the patient

is characteristic (Fig. 239): he stands with the head inclined to the injured side, thus relaxing the pull of the sternocleidomastoid muscle upon the inner fragment. The shoulder upon the side fractured is depressed; the elbow and

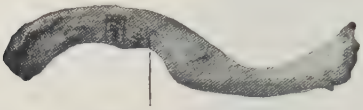


Fig. 235.—Fracture at the middle of the clavicle (Warren Museum).

Fig. 236.—Fracture at the middle of the clavicle (Warren Museum).

forearm upon this same side are supported by the well hand. This is the attitude of greatest comfort and muscular balance. The shoulder—*i. e.*, the

Fig. 237.—Fracture of the clavicle at the outer end. No displacement (Warren Museum).

Fig. 238.—Fracture of the clavicle, showing considerable deformity (Warren Museum).

space between the base of the neck and the greater tuberosity of the humerus —is shortened upon the injured side (Fig. 239). If the fracture lies within the limit of the coracoclavicular ligament or outside of it, there will be no

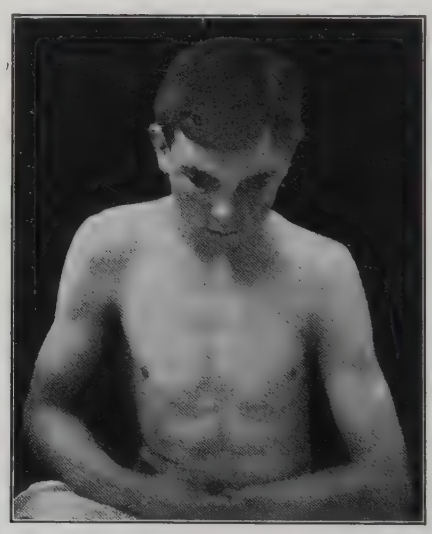


Fig. 239.—Comminuted fracture of the left clavicle. Attitude characteristic; deformity visible; the fracture was sutured with wire (Mixter).

appreciable displacement. The diagnosis under these circumstances will be difficult. Localized tenderness and pain and the disability of the arm will suggest the lesion present.

Fracture of the Clavicle in Childhood.—More than one-third of all fractures of the clavicle occur in children under five years of age. A trivial

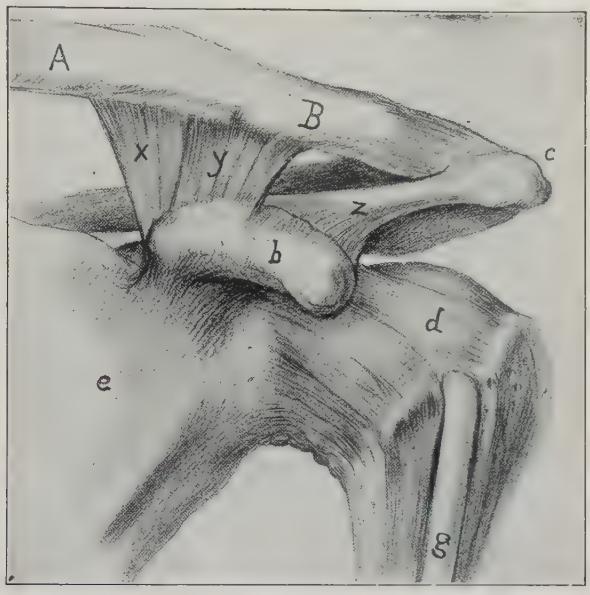


Fig. 240.—A fracture of the clavicle at *A*, the usual situation, would result in considerable displacement of the inner fragment. A fracture situated within *x y* is usually little displaced; *x*, conoid ligament; *y*, trapezoid ligament; *z*, coraco-acromial ligament; *c*, acromion; *b*, coracoid process; *e*, scapula; *d*, head of humerus; *g*, long tendon of the biceps.

injury is the usual cause of the fracture. A little child may fall from a low chair or out of bed and fracture the clavicle. The fracture is almost always incomplete or greenstick (see Fig. 244).

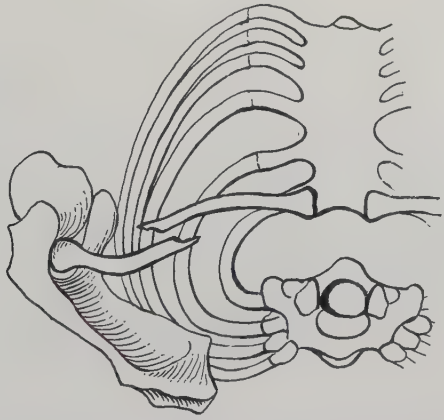


Fig. 241.—A diagrammatic drawing to illustrate that when the clavicular prop is broken and the support of the clavicle is absent the whole shoulder falls inward and forward and the scapula tilts outward (after Davis-Peotti).

The child cries upon moving the arm. Lifting the child by placing the hands in the armpits causes pain. The arm of the injured side may be used

as naturally as the other, or there may be some disability, perhaps simply a disinclination to use the arm. If the fracture is a greenstick one, a tender

Fig. 242.—Fracture of the outer end of the clavicle. The outer fragment falls inward (after Davis-Peotti).

swelling appears at the seat of the fracture. If the fracture is complete, an unevenness will be felt at the seat of fracture according to the amount of

Fig. 243.—Fracture of the clavicle a little to the outer side of the middle. The inner fragment is displaced upward by the pull of the sternomastoid muscle. The outer fragment drops down by gravity and inward and forward. Note the trapezius, deltoid, sternomastoid, pectoralis minor a glimpse; the pectoralis major. The brachial plexus and the subclavian vessels are seen behind the fracture (after Davis-Peotti).

displacement. The displacement is usually slight in childhood. The characteristic attitude seen in adults (Fig. 239) is much less marked in children,

and if the fracture is greenstick, there is no tilting of the head and depression of the shoulder. If the child, as so often occurs, persistently holds the head so that a careful examination is impossible, then it is best to place

Fig. 244.—Roentgenogram of a partial fracture of clavicle. Note at white line the line of cleavage (Arial George).

the child on its back, and while its legs and arms are held firmly the head and shoulder may be gently and gradually separated. The examination can then be satisfactorily completed.

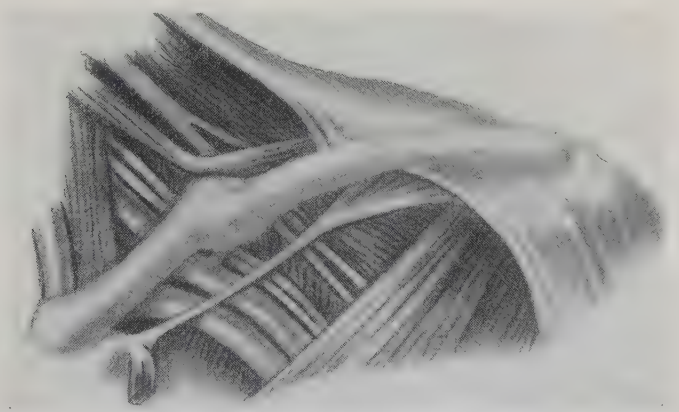


Fig. 245.—A drawing to illustrate the relations of structures behind and near the clavicle. Note the callus of a fracture of the clavicle. It lies and presses upon the cord of the brachial plexus and disabling symptoms may arise therefrom. Note omohyoid, scalenus anterior, the trapezius and deltoid muscles; the subclavian vessels, the cords of the brachial plexus (after Davis-Peotti).

Treatment in Adults.—The displacement should be corrected and the corrected position maintained (Figs. 249, 250). The indications are to

carry the shoulder and with it the outer fragment upward, outward, and backward.

The Recumbent Treatment.—The recumbent posture may be maintained by many cases of fracture of the clavicle for twelve hours, two days, or a week as preliminary to any retentive ambulatory dressing. Such supine bed treatment will be conducive to the elimination of muscle spasm, displacement by gravity, and marked deformity. The displacement is most satisfactorily corrected by the patient lying recumbent upon a firm mattress. The weight of the shoulder in this position does not impede reduction as in the upright

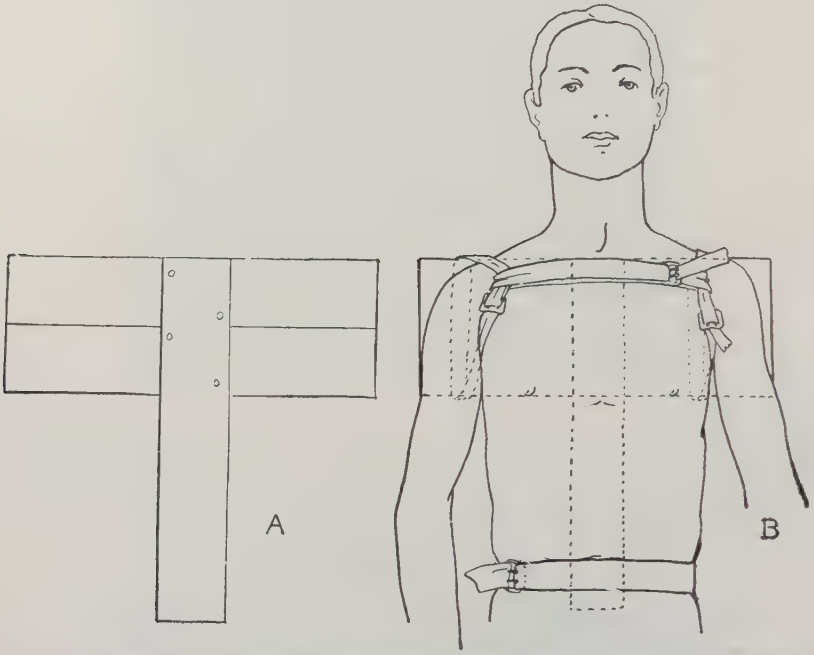


Fig. 246.—A, Clavicular cross (made of splint board), the two pieces, the width of the shoulders, being tacked to a vertical piece reaching from the shoulder to the sacrum (see dotted line). B, Method of application of clavicular cross (for purposes of simplification the padding is not shown). The surface of the splint in contact with the skin should be abundantly padded with cotton and covered with a bandage. The affected shoulder is lifted up, backward and outward, and secured to the cross arms of the splint by straps or a figure-of-8 bandage. The lower part of the vertical pieces is pushed in close to the sacrum and held by adhesive plaster or buckle and straps.

position, but assists it. A firm and small pillow should be placed between the shoulders. The shoulders fall backward of their own weight over the pillow, carrying the outer fragment backward at the same time. Padding of the fragments of the clavicle, the application of pressure to the elbow, may be more satisfactorily accomplished in the recumbent than in the upright position. Union ordinarily occurs within three weeks. At the time of union or shortly after the patient may be allowed up with a simple retentive dressing, a sling, and a swathe. The bed treatment is hard to enforce because the fracture is the cause of so little real permanent disability. If there is much displacement and the deformity cannot be corrected and held

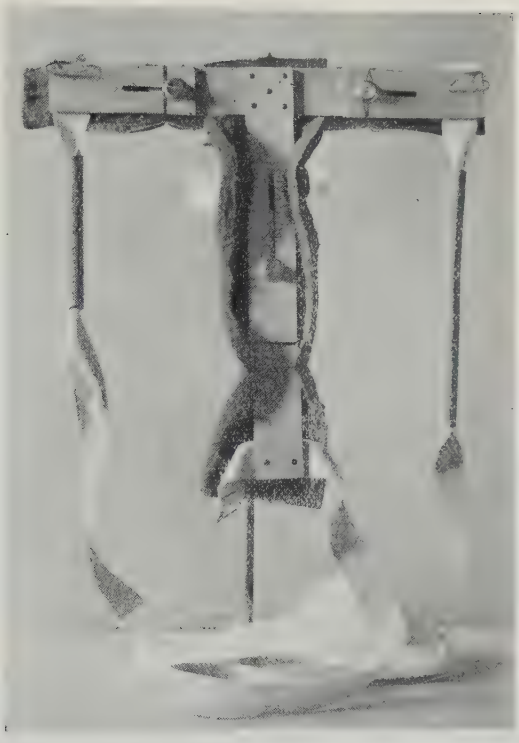


Fig. 247.—Clavicular cross of Landry. Note adjustable arms and upright, felt padding, webbing straps covered with rubber tubing, buckles, body webbing strap at lower end of upright. Inexpensive, adjustable, efficient, satisfactory (Landry).

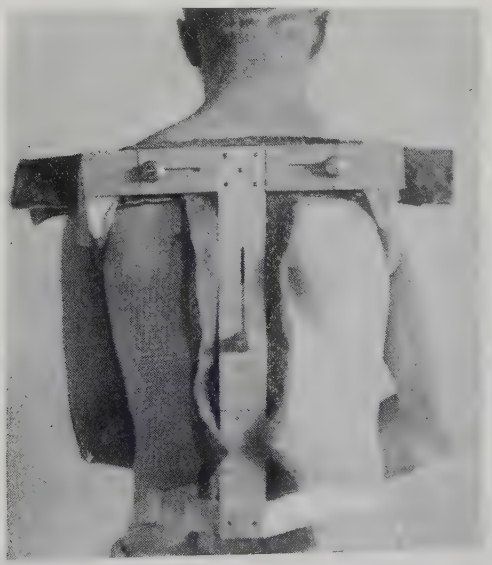


Fig. 248.—Clavicular cross of Landry applied (see Fig. 247).

Fig. 249.—Fracture of the clavicle. Method of correction of falling inward and downward of shoulder in overriding of fragments previous to the application of the clavicular cross or the modified Sayre dressing.

Fig. 250.—Fracture of the clavicle. Same as Fig. 249. Posterior view, showing extremely forced backward position of shoulders.

properly, the bed treatment is indicated. In the simultaneous fracture of both clavicles the recumbent bed treatment is the best (see Operative Treatment of Fracture of the Clavicle).

Fig. 251.—Fracture of the clavicle. Barrel stave splint. Anterior view. Used with plaster-of-Paris bandage effectively (H. A. Royster, Annals of Surgery).

Fig. 252.—Fracture of clavicle. Barrel stave splint applied. Posterior view. Note turns of bandage (H. A. Royster, Annals of Surgery).

The Barrel Stave Dressing for Fracture of the Clavicle.—Royster has well illustrated this very satisfactory dressing. It was used as the military fixation apparatus with decided success. It consists of a flat thin piece of wood

placed on the front of the chest below the clavicle reaching almost to the point of the shoulders. The two shoulders are held steadied to it by a figure-of-8 bandage, as shown in Figs. 251, 252.

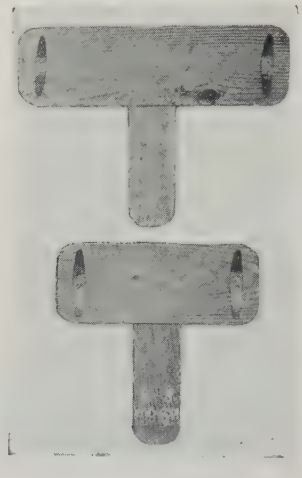


Fig. 253.—Wooden cross splints (Hawley).

Fig. 254.—The Hawley clavicle splint applied. Anterior view.

Fig. 255.—The Hawley clavicle splint applied. Posterior view.

In fractures of the clavicle without the common tendency to a dropping of the outer fragment this form of apparatus is effective.

The military use of the *wooden cross* between the scapulæ is very effective and simple. The shoulders are held to the cross much as in the barrel stave

splint by a bandage. By the wooden cross splints the shoulders are drawn backward. Hawley has devised a simple splint of this kind (Figs. 253–255).

The Modified Sayre Dressing.—The shoulder and arm are unwieldy in adults. It is, therefore, necessary in treating a fracture of the clavicle by an ambulatory method to secure a very firm hold upon the shoulder in order to maintain the clavicular fragments in a good position. Ordinarily the clavicular cross is the best dressing.

The modified Sayre adhesive-plaster dressing secures for an ambulatory patient only a fair degree of fixation following fracture of the clavicle. It is applied as follows: Provide three strips of adhesive plaster, 4 inches wide, and long enough to extend once and a half around the body.

Fig. 256.—Fracture of the left clavicle. Modified Sayre dressing. Towel circular of upper arm held by adhesive plaster. Adhesive plaster strap ready.

Fig. 257.—Fracture of the left clavicle. First adhesive plaster strap applied. Shoulder carried backward. Fixed point established above middle of humerus.

The skin surfaces that are to come in contact—namely, the axilla and chest and forearm—are separated by compress cloth and powder. A dressing towel, folded like a cravat, is snugly pinned high up about the upper arm (Fig. 256). This towel may be held neatly by a strip of adhesive plaster. One end of the first adhesive strap is fastened loosely about the towel-protected arm with a safety-pin. While an assistant holds the shoulder well back the arm is carried backward, and held by the fastening of the first adhesive strap about the body (Fig. 257). This affords a fixed point at the middle of the upper arm. The second strap, with a hole in it to receive the point of the elbow, is started upon the posterior surface of the injured shoulder (Fig. 258) and carried under the elbow of the injured side and over the well shoulder (Fig. 259). The forearm is flexed and rests upon the chest. In

Fig. 258.—Fracture of the left clavicle. First adhesive plaster strap applied. Second adhesive plaster strap being applied. Hole in plaster for olecranon visible. Note pad for wrist and folded towel protecting skin of arm and chest.

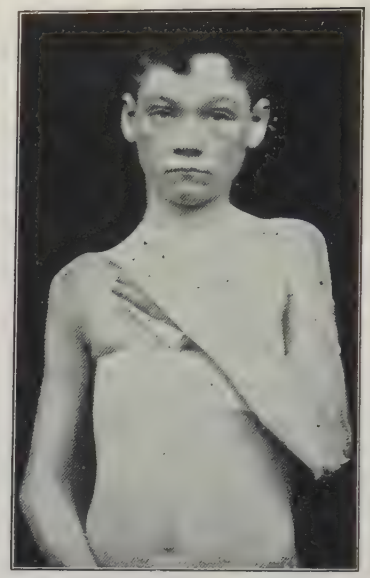


Fig. 259.—Fracture of the left clavicle. First and second adhesive plaster straps applied. Pad in left hand. Shoulder pulled backward and elevated.

Fig. 260.—Fracture of the right clavicle. Modified Sayre dressing. Posterior view. Shoulder elevated and pulled backward. Folded towel seen in axilla for protection to skin.

Fig. 261.—Fracture of left clavicle. Method of application of a Velpeau bandage. Note the order and direction of the turns 1, 2, 3, 4, and 5. Note position of the forearm and arm of the uninjured side.

applying this second strap the shoulder is raised and the elbow is carried forward, thus forcing the shoulder slightly upward and backward of the

fixed point used as a fulcrum (Fig. 260). A third strap may be placed around the trunk and arm to steady all in good position. Over this dressing may be put a Velpeau bandage for the comfort of the support which it affords (Fig. 261). The adhesive plaster should be covered with bits of gauze bandage, in part to protect the skin from undue chafing, only sufficient plaster surface remaining uncovered to prevent the straps from slipping. Occasionally pads (Fig. 262) upon the clavicle may be used to correct the deformity, but the bone is so subcutaneous that the skin cannot bear great pressure without damage. If pads are used the skin beneath them must receive frequent inspection.

Fig. 262.—Fracture of right clavicle and subluxation of the acromioclavicular joint. Notice elevation of shoulder by pressure on the flexed elbow and counterpressure on the clavicle by a bandage and a pad (×) placed internal to the acromioclavicular joint.

Conteaux suggests that the patient with a fracture of the clavicle lie on a firm mattress close to the edge of the bed, without any pad between the shoulders. The whole upper extremity is allowed to hang over the edge of the bed in abduction, unsupported. In two to four hours (Crile), sooner if the pain or swelling of arm is extreme, the forearm is flexed almost to a right angle. The forearm and elbow are just barely supported by a stool close to the bed without any upward thrust from the stool. Thus the upper arm is permanently abducted, hanging over the edge of the bed, and the forearm and elbow supported.

The patient by Conteaux's method remains in bed for ten or twelve days until union has begun and then is allowed up with a Velpeau bandage or a

swathe to upper arm and body and a sling. The co-operation of the patient is essential to the success of this treatment. Obviously it is a method only applicable to intelligent adults (Crile).

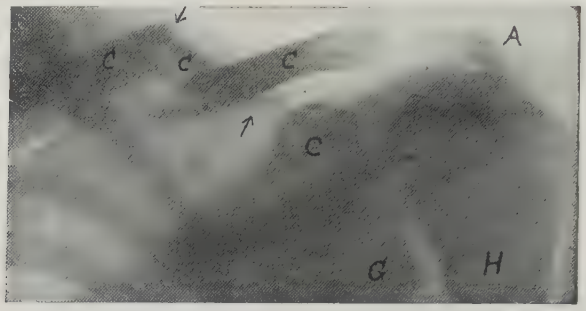


Fig. 263.—Double fracture of the clavicle. Note the displacement of the fragments: *A*, Acromion; *H*, humerus; *G*, glenoid; *C*, coracoid process; *C*, *C*, *C*, each on a fragment of the clavicle. The arrows point to the sites of the fractures.

Treatment in Children.—The skin of the child must be protected by powder and careful drying before the arm is done up. If it is a greenstick fracture and there is slight deformity, this deformity should be corrected by pressure with the thumbs. An anesthetic should be used. After the deformity is corrected and in cases without deformity it is necessary simply to restrain the movements of the arm for two weeks. This is best accomplished by a cotton swathe about the body and upper arm, held by straps over the shoulders and by a cravat sling. In warm weather and also in cool weather, for that matter, the arm is to be

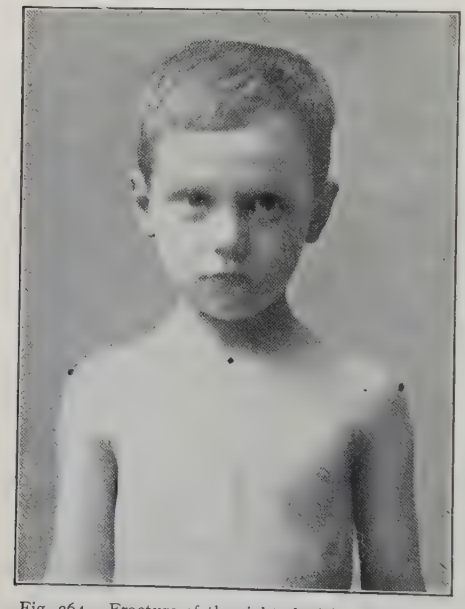


Fig. 264.—Fracture of the right clavicle. Shortening of the shoulder.

Fig. 265.—Fracture of right clavicle showing amount of callus present when union was completed. The deformity from this callus entirely disappeared after several weeks.

inspected frequently, as often as every third day, when all the dressings are removed, the parts bathed with soap and warm water, powdered, and the simple retentive dressing reapplied. With this care only can chafing be avoided. If it is a complete fracture, the wooden cross and at times the modified Sayre protected adhesive plaster dressing should be used as in adults. The skin is to be carefully protected and the dressing most assiduously watched. It requires but forty-eight hours for great chafing to occur with resulting discomfort and the slow healing of abraded surfaces which often

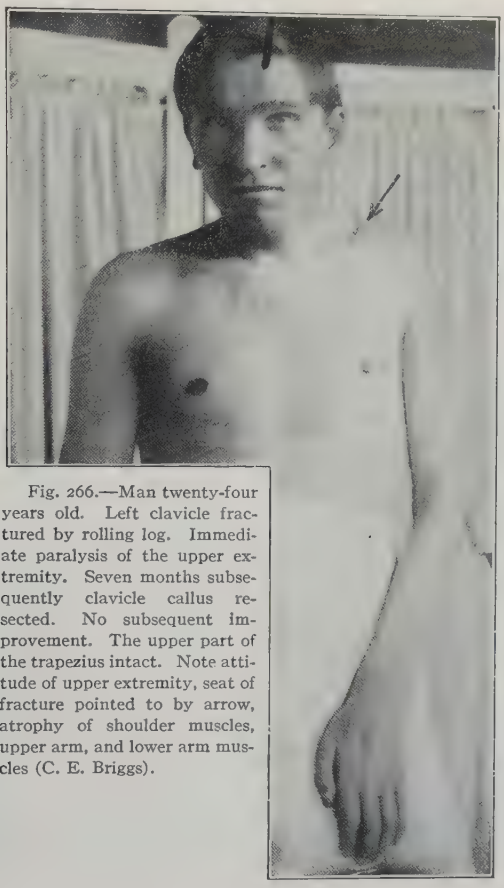


Fig. 266.—Man twenty-four years old. Left clavicle fractured by rolling log. Immediate paralysis of the upper extremity. Seven months subsequently clavicle callus resected. No subsequent improvement. The upper part of the trapezius intact. Note attitude of upper extremity, seat of fracture pointed to by arrow, atrophy of shoulder muscles, upper arm, and lower arm muscles (C. E. Briggs).

results. If union is firm after two weeks or two weeks and a half, the plaster dressing should be removed and the shoulder put up in a simple retentive swathe and sling, at first, inside the clothes; after three weeks, outside the clothes. In very active children the sling should not be removed until four weeks have elapsed. Massage should be given to the forearm, elbow, and shoulder after the first week, together with active supported motion of the elbow. In both children and adults the protected adhesive plaster dressing should be reapplied at least once every ten or twelve days. If the dressing chafes or slips, it may need more frequent renewal.

Prognosis.—Useful arms and shoulders usually result after fracture of the clavicle. Almost all complete fractures of the clavicle with displacement of fragments, after repair has taken place, show unmistakable evidences of deformity at the seat of fracture, a diminution in the width of the shoulders, and in many instances in children a slight lateral deformity of the spinal column (Fig. 264). Fractures within the coracoclavicular ligament having little displacement of fragments show no resulting deformity. Very great deformity does not preclude a useful arm. An un-

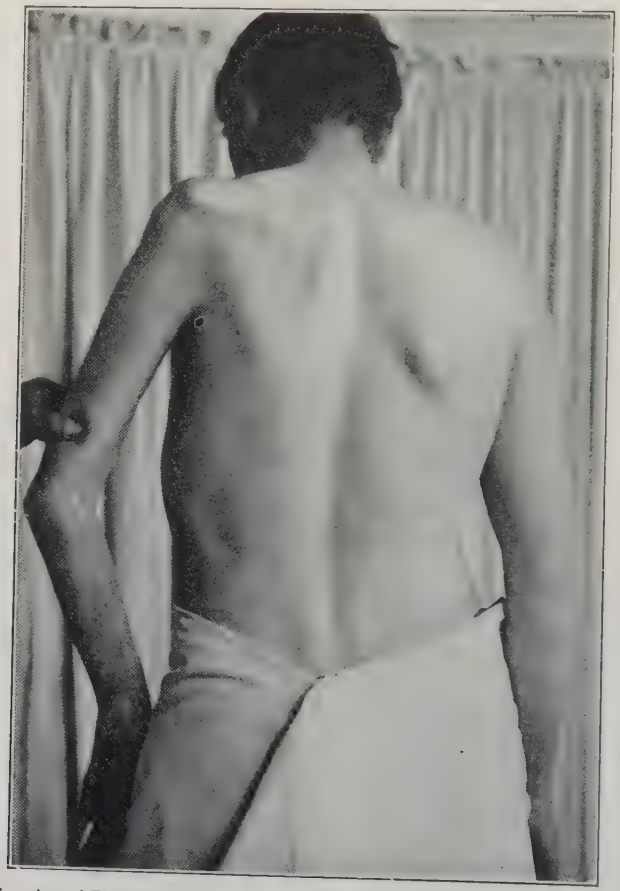


Fig. 267.—Posterior view of Fig. 266. Note position of the upper extremity and the atrophy (C. E. Briggs).

united fracture of the clavicle is unusual; it may exist and cause no especial inconvenience; it may be unknown to the patient. An ununited fracture of the clavicle with considerable callous formation may simulate malignant disease of the bone. Laboring men are rarely kept from their work more than two months. Fractures of the clavicle in young children, if carefully treated, should unite with practically no deformity or disability. Green-stick or incomplete fractures may show a general bowing of the whole bone which it has been impossible to correct.

Operative Treatment.—*In Recent Fractures.*—If there is great displacement which cannot be held reduced, if sharp fragments threaten vessels or nerves, if there is pressure upon either nerves or blood-vessels, if the fracture is a comminuted one, and if the bone is fractured in two or more places (multiple fractures), it is wise to consider operative measures, especially if the recumbent posture is ineffective. The fragments can be exposed, replaced, and held in position by suturing. It is wise in suturing the fracture of the clavicle to use if practicable an absorbable suture material if it is effective. Silver or aluminum bronze wire or a Sherman steel plate and screws may be employed. Good results follow this treatment. After operation for fracture of the clavicle recumbency and a simple retentive dressing of a swathe and cravat sling will be needed. It should be worn for at least three weeks.

In Ununited Fractures.—If the cause of delayed union of the fracture is a misplaced bony fragment, an interposed strip of fascia or periosteum, or an interposed subclavius muscle, operative interference may be undertaken with a reasonable expectation of securing a good result. If, on the other hand, non-union has existed for a long period (a year or more), it is highly probable that the ends of the fragments will be so attenuated that refreshing these ends for suture would shorten the fragments to such an extent that suture would be impossible. Bone-grafting may be employed if all other methods fail.

II. FRACTURES OF THE SCAPULA

The spine and acromial process, the coracoid process, and the vertebral and axillary borders of the scapula can be palpated with comparative accuracy. Fracture of the scapula is of rather unusual occurrence, and always follows great violence (Figs. 268–270).

Fracture of the body of the scapula is transverse between the axillary and vertebral borders or comminuted in various directions (Figs. 272, 273, 277).

Crepitus, abnormal mobility, local swelling, and tenderness are present. Pain is felt upon attempting to adduct and to abduct the arm. It may be impossible to raise the arm to the head.

Fracture of the Acromial Process of the Scapula.—The epiphysis of the acromion unites with the scapula about the twentieth year. If there is a fracture present, and not a separation of the epiphysis, which sometimes occurs, the line of fracture is ordinarily outside the acromioclavicular joint. A fracture may occur through the acromion nearer to the spine of the scapula.

Localized pain, swelling and tenderness, and a flattening of the shoulder are present. Crepitus may at times be felt. If the fracture is inside the acromioclavicular joint the flattening of the shoulder will be considerable. The head of the humerus is felt in the glenoid cavity, thus ruling out a dislocation.

Fracture of the neck of the scapula is most unusual. If present, it may be mistaken for a dislocation of the humeral head.

The acromial process is prominent. The upper arm is lengthened. On lifting the arm forcibly upward with the elbow flexed, the deformity is cor-

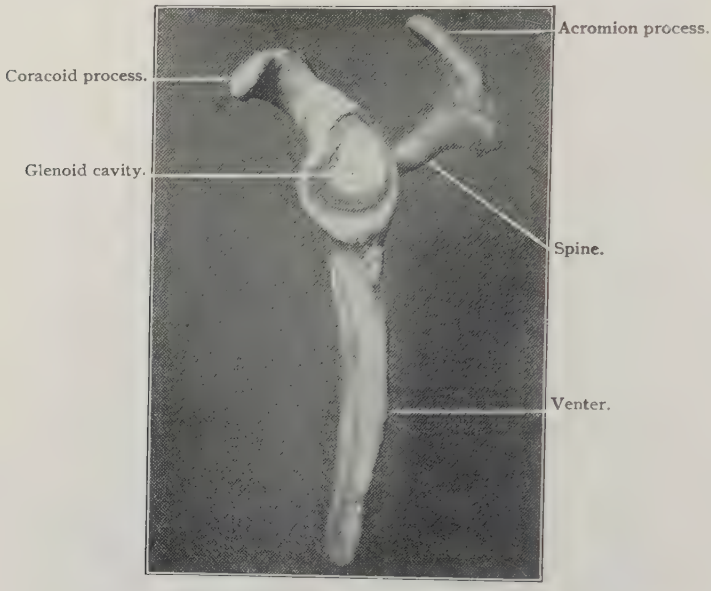


Fig. 268.—Normal scapula. Axillary view.

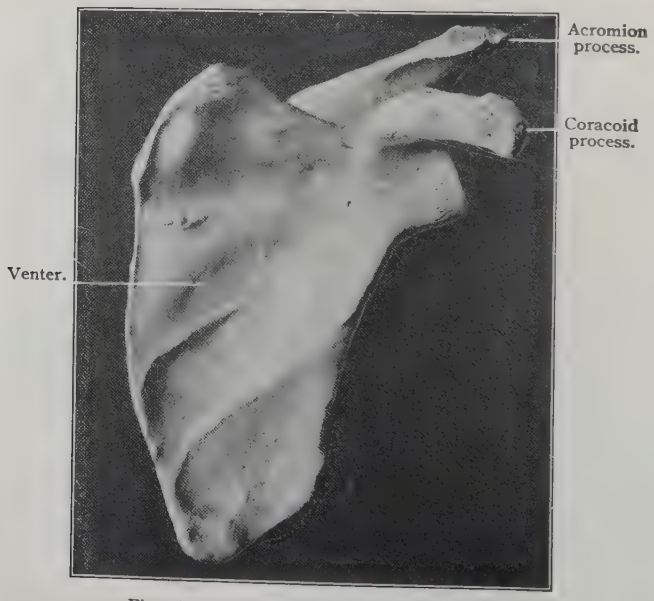


Fig. 269.—Normal scapula. Ventral view.

rected, and crepitus is detected. The deformity recurs if this upward pressure is removed. The reappearance of the deformity and the crepitus serve

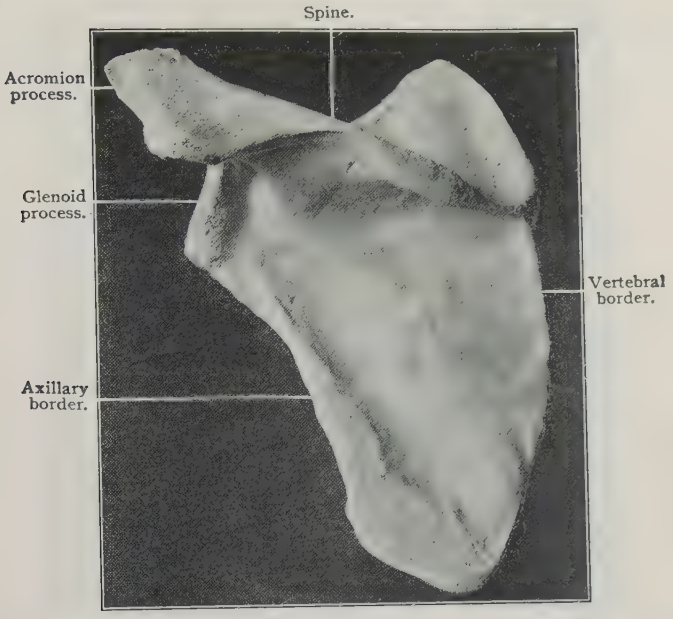


Fig. 270.—Normal scapula. Dorsal view.

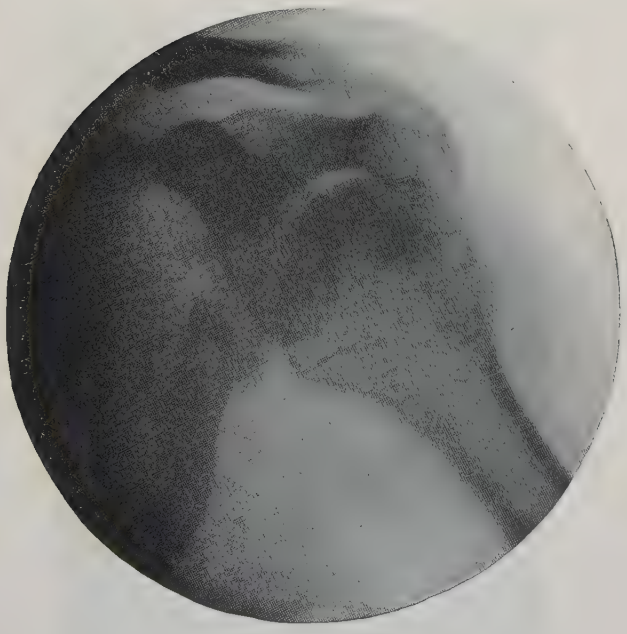


Fig. 271.—Fracture of the scapula behind glenoid fossa (Dodd).

to distinguish this injury from a dislocated shoulder. In a thin person palpation of the edges of the glenoid cavity itself will prove rather satisfactory; the crepitus and abnormal mobility can thus be more accurately located.

Fig. 272.—Fracture of the body of the scapula. Bony union with moderate displacement (Warren Museum Specimen 8111).

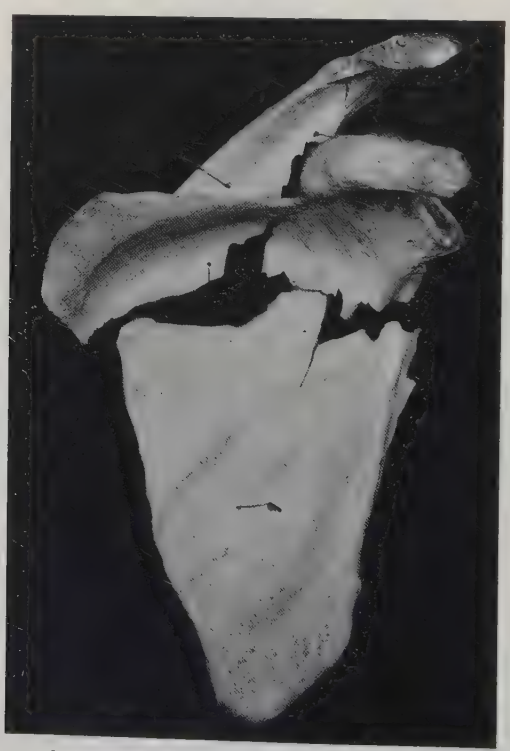


Fig. 273.—Multiple fractures of scapula. Railroad accident. Man, forty-three years of age. Lived but one day (Warren Museum, Specimen 6028).

Treatment in General.—Immobilization of the upper extremity, except the forearm and hand, is necessary. Localized pressure may assist in retaining fragments in place.

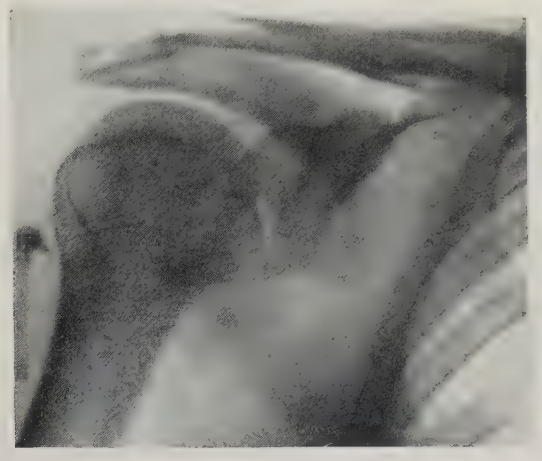


Fig. 274.—Fracture of the neck of the glenoid of the scapula (Holmes).

If there is fracture of the body of the scapula, the forearm should be flexed to a right angle and held in a sling. The skin surfaces coming in contact should be protected by powder and compress cloth. A swathe of

Fig. 275.—Fracture through glenoid of scapula parallel with axillary border of scapula—an unusual type (Holmes).

cotton cloth should be fastened about the upper arm and trunk. If the cloth swathe is not sufficient to hold the scapula steady, a swathe of adhesive plaster should be used broad enough to extend from the acromion to the elbow.

Treatment of fracture of the neck of the scapula with some displacement may be adequately treated by the recumbent position and traction in the abducted upper extremity. The degree of abduction is to be determined

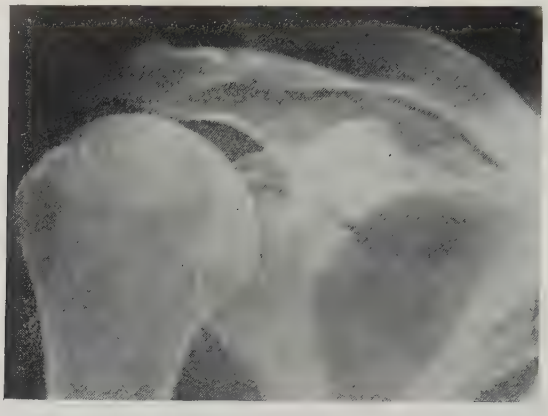


Fig. 276.—Fracture through the upper part of the glenoid cavity of scapula (Arial George).

by the use of the fluoroscope. Traction on the upper extremity in the abducted position will necessitate elevation of that side of the bed to secure countertraction (Hey-Groves).

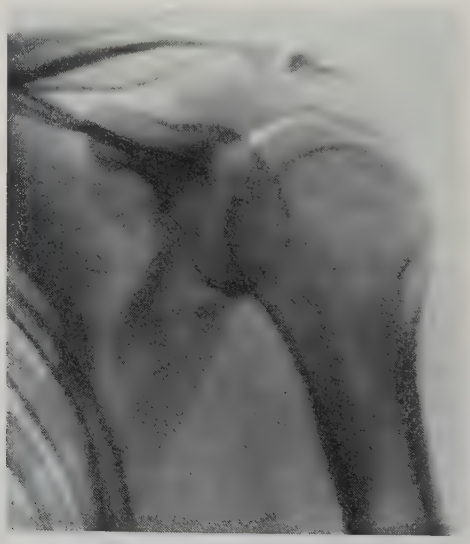


Fig. 277.—Fracture of the scapula through the body of the bone. Note normal relations of head and the glenoid.

Fracture of the Acromial Process.—The skin surfaces must first be protected from chafing. The forearm being flexed, pressure upward should be made upon the elbow, so as to lift the arm and relax the pull on the small acromial fragment. At the same time counterpressure is made upon the

inner fragment and incidentally upon the inner shoulder (see Fig. 262). This pressure and counterpressure will hold the part reduced. The bandage must be inspected frequently each day in order to detect and to re-

Fig. 278.—Fracture of the spine and body of the scapula (Holmes).

lieve too great pressure upon the elbow and bony parts of the shoulder. Broad canvas straps and buckles may be adjusted to this lesion.

Union will take place in from three to four weeks. It is extremely difficult to maintain the reduction of the fragment of the acromion by any apparatus.

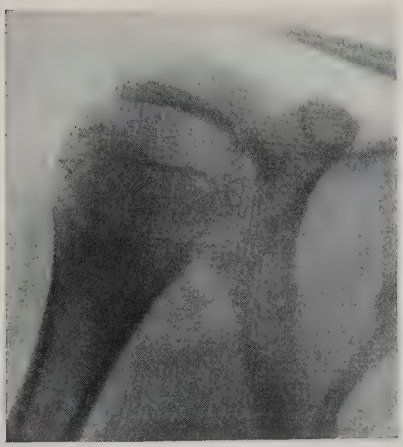


Fig. 279.—Fracture of the glenoid (Holmes).

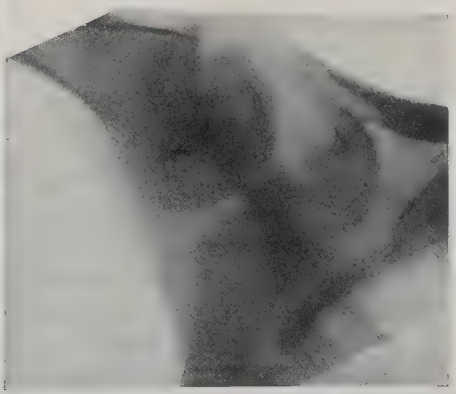


Fig. 279A.—Same as Fig. 279 in abduction (Holmes).

The one previously suggested meets the indications better than any other. Massage will materially assist in hastening the absorption of blood and will relieve pain. No very great functional disability results if union occurs with slight bony displacement.

CHAPTER IX

EXTENSION AND COUNTEREXTENSION

Principles of fixed traction (Thomas)—Principles of mobile traction (Hodgen)—Method by fixed traction—The Thomas splint—Description of—The choice of Thomas splint—Application of extension strips—The slinging of the limb—Putting on of Thomas splint—Fixing traction band to the Thomas splint—Suspending the Thomas splint—Method by weight traction—The Pearson knee flexion attachment for the Thomas splint.

METHODS OF SECURING EXTENSION AND COUNTEREXTENSION

THESE methods are appropriately grouped as: Fixed Traction and Mobile Traction (Hey-Groves).

I. **Fixed Traction.**—Early correction of length and alignment without or preferably with the assistance of a general anesthetic and then retention in a fixed splint with fixed traction.

The Thomas Principle of Traction and Countertraction.—(1) The Thomas splint (Figs. 280, 286). Traction to the foot of the splint; countertraction on the tuber ischii of the patient (see Figs. 937, 938).

(2) Plaster-of-Paris spica (see Figs. 870, 871, 879).

II. **Weight or Mobile Traction.**—Early complete or gradual correction of shortening and malalignment with or without an anesthetic with continuous weight traction, which acts constantly until union is firm, the traction then being transferred to the natural callus of repair.

The Hodgen Principle of Traction, Countertraction, and Suspension.—(1) The Thomas splint, slung, with traction by weight and pulley. The traction is made on the limb direct to the pulley, or through the splint to the pulley.

(2) The Hodgen splint, slung, traction to the leg through a pull on the splint. The original Hodgen method (see Figs. 944, 945, 948, 949).

(3) Traction with the aid of the Steinman nail or caliper. The most efficient traction method (see page 217).

All other methods of traction and suspension, traction and fixation are modifications of or combinations of the Thomas (fixed traction) principle and the Hodgen (mobile traction) principle. Let the student master these two principles and he understands all.

I. **Method by Fixed Traction.**—The Thomas splint is a support for the limb while it is being extended. The splint (see Fig. 936), as used for fractures of the lower extremity, consists of a metal ring covered with leather, and extending from the ring are two side bars joined below the foot by a cross bar. The ring of the splint should fit the upper end of the thigh loosely, lying posteriorly in the fold of the buttock, so as to take a bearing upon the tuber ischii. The part of the ring in contact with the tuber ischii should be more thickly padded than the rest of the ring.

Commercially, the splint may be purchased from instrument makers ready to be used. Harvey R. Pierce Company, Philadelphia, Pa., manu-

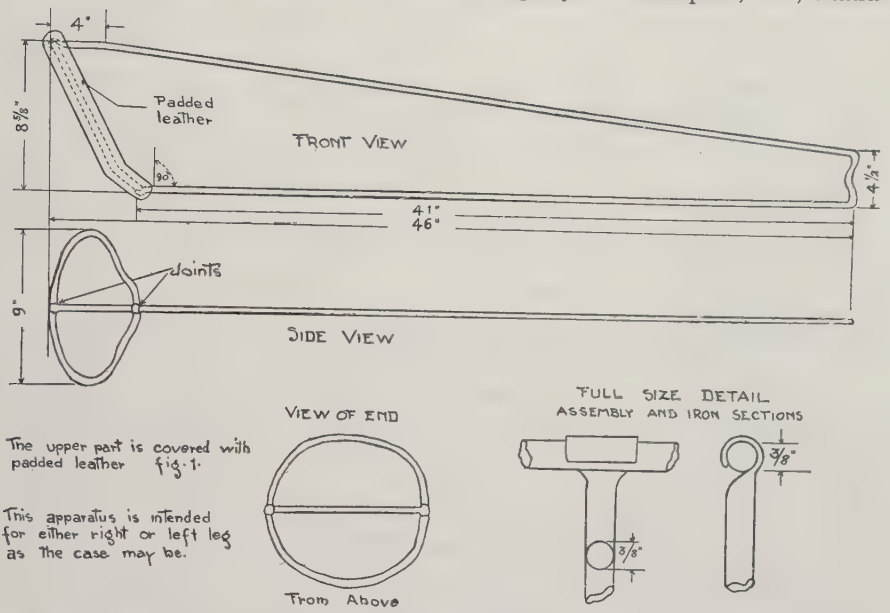


Fig. 280.—Specifications for Thomas traction leg splint. (Fracture Committee American College of Surgeons, Blake, Osgood.)

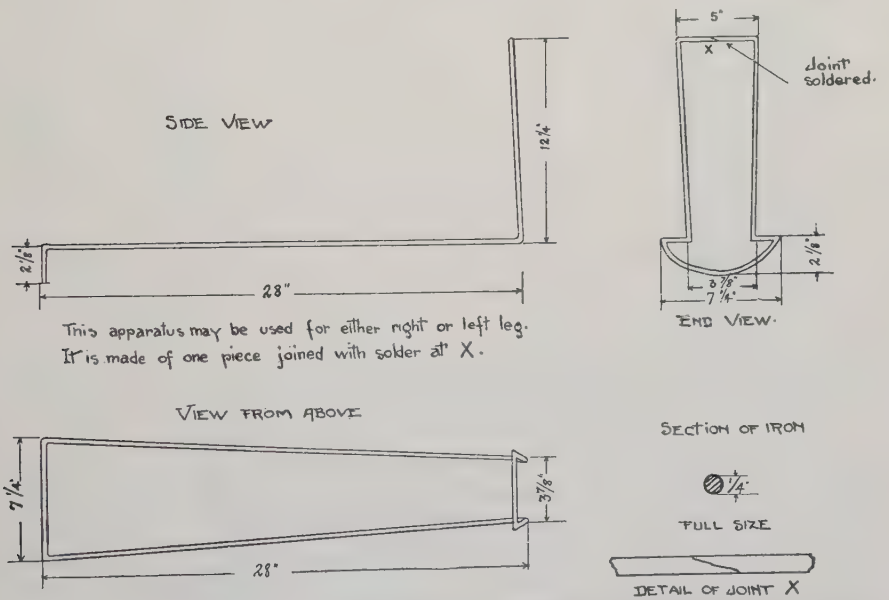


Fig. 281.—Specifications for Cabot posterior wire leg splint. (Fracture Committee American College of Surgeons, Blake, Osgood.)

facture the Pierce Alloy Thomas splint, light in weight, transparent to the Roentgen ray, and strong. Ordinarily it is 46 inches long over all. It may

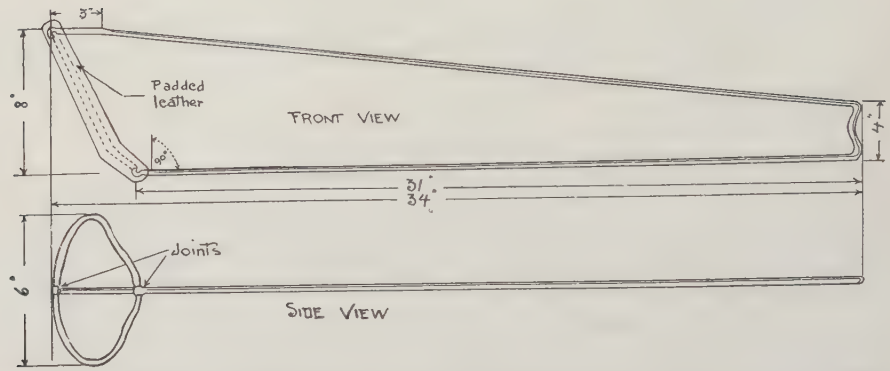


Fig. 282.—Specifications for Thomas traction leg splint. Child's size (Fracture Committee American College of Surgeons, Blake, Osgood).

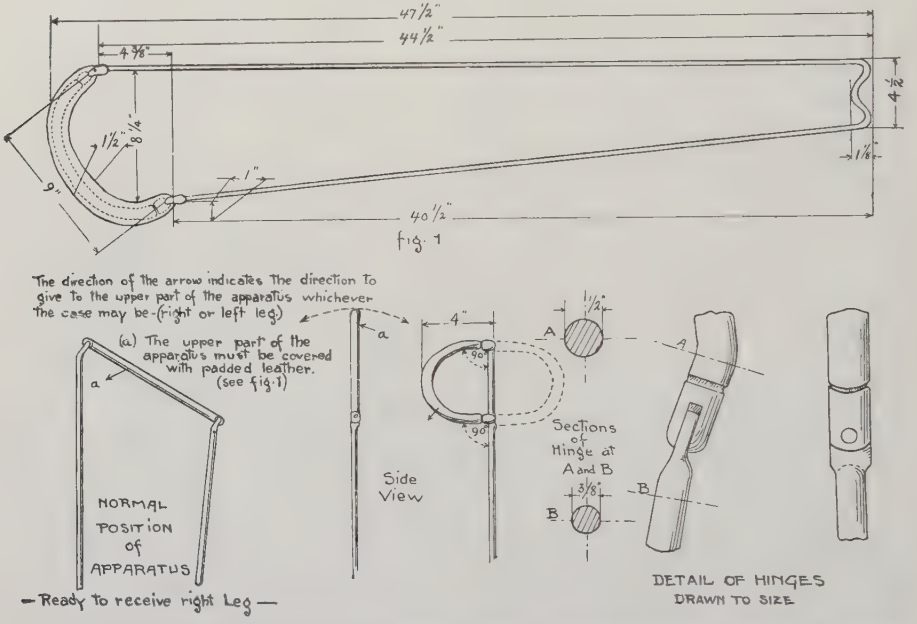


Fig. 283.—Specifications for hinged half ring thigh and leg splint (Blake-Keller model). (Fracture Committee American College of Surgeons, Blake, Osgood).

Fig. 284.—Another type of Thomas leg splint.

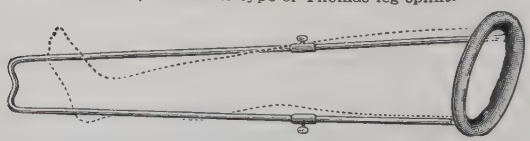


Fig. 285.—Robert Jones' extension leg splint can be taken apart in middle.

be had for adults in the following sizes—rings of 25 and 28 inches in diameter, inside measurement. The splint should be long enough so that the two uprights or lateral bars extend some distance, 6 inches or more, below the sole of the foot when the ring is pressed against the tuber ischii. The splint may be made longer than 46 inches if desired. This is the length ordinarily used. The ring may be considerably larger than the circumference of the thigh at the perineal level, provided the posterior portion of the ring is well padded and adapted to the tuber ischii. It is found impracticable to have

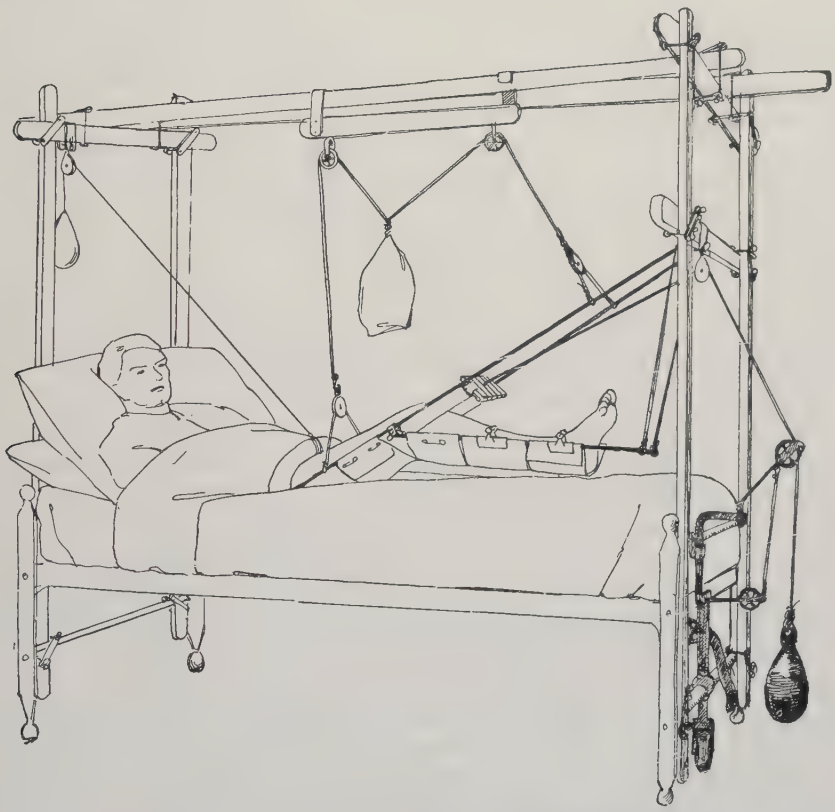


Fig. 286.—Balkan frame, illustrating the method of applying and suspending the Thomas traction leg splint with the Pearson hinged knee attachment. Lower leg band over heel incorrect. (M. G. H. Conference.)

rings of Thomas splints fitting accurately to each patient, which, of course, would be ideal. The ring is placed by the instrument maker at 45 degrees with the upright of the splint on the inner side of the thigh and leg. The child size of the Thomas splint is 34 inches over all, with rings 18 and 20 inches in diameter, inside measurements.

The Choice of Thomas Splint.—A Thomas splint is selected whose ring fits the patient so that the hand can easily be passed between the ring and the anterior surface of the thigh at the perineal level. The smaller the ring, according to this measurement, the easier it is to maintain the splint in

position. Very large rings are less comfortable for the patient. Before applying the ring the leather covering is softened with common soap. In the upkeep of the splint after it is put on, the leather ring, where it comes in contact with the ischium, should be soaped by the nurse once daily. The proper adjustment of a Thomas splint is such that the ring, if it is to exert pressure on the tuber ischii, should fit exactly without outside assistance. An oversized ring may be made to fit better if it is slung to an overhead frame—the ring is thus snugged against the ischium.

Application of extension with Sinclair's glue and gauze and woven bandage strips (see p. 548): The use of Sinclair's glue is sometimes preferable to the use of ordinary adhesive plaster. The adhesive plaster tends to slip and the skin becomes damaged, resulting in great discomfort to the patient and the likelihood of infection of the abraded skin.

The Sinclair foot piece (Figs. 1224, 1225) or some modification may be used to control the ankle and foot, and to some degree the distal fragment of a fracture of the tibia (Fig. 941). In the absence of this foot piece a strip of gauze may be glued to the sole of the foot and the foot slung overhead (Fig. 300).

The Slinging of the Limb in the Thomas Splint.—Each sling is looped around the inner bar or upright of the splint, carried under the leg, and fixed on the outer upright by means of large safety-pins or clips. The best material for this sling is a thin flannel.

Application of the Thomas Splint.—We are assuming that the patient is completely anesthetized, but not regarding the seat of the fracture. (See fracture of the thigh and fracture of the leg.) The extension strips having been applied to the proper level on thigh or leg, the leg is held by traction and by supporting hands and the ring of the splint is slipped over the foot and limb and pushed home against the tuber ischii. The extension strips are securely tied at the end of the splint while traction is being maintained, the countertraction being against the tuber ischii.

Method of Tying Traction Bands to Thomas Splint (see Fig. 972).—See Osgood's method of twisting traction bands to increase or diminish traction. The slings are placed at appropriate levels to support the limb comfortably and effectively in maintaining the desired position of the fragments (see Figs. 941, 942). The foot is cared for by skate (see Fig. 941) or traction strap.

The Suspending of the Thomas Splint.—The limb having been placed in the Thomas splint, the splint is slung or hung from the overhead frame or Balkan frame by cords attached to the two ends of the splint—that is, the upper ring and the lower end beneath the foot. Thus, we have the rigid fixed traction in the slung Thomas splint. This is a satisfactory method for temporary transport (see Figs. 970, 971). The Hodgen splint may be used in the same fashion (see Fig. 977).

In a properly balanced suspension and traction the shifting of the body is automatically accommodated so that the alignment of the fracture fragments is undisturbed.

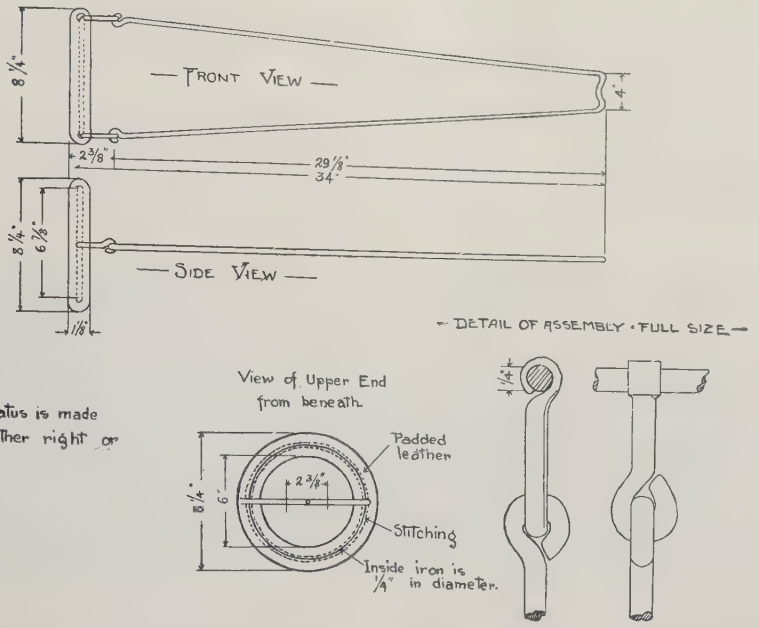


Fig. 287.—Specifications for Murray's modified Thomas traction arm splint. (Fracture Committee, American College of Surgeons, Blake, Osgood.)

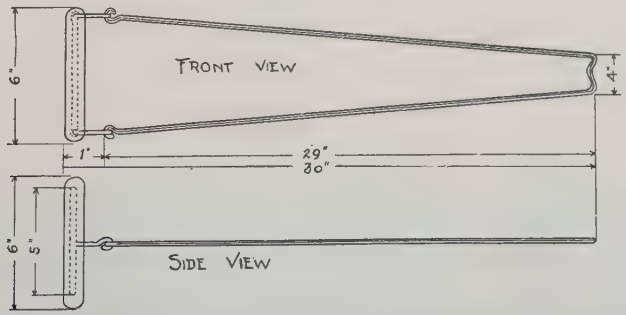


Fig. 288.—Specifications for Murray's modified Thomas traction arm splint. Child's size. (Fracture Committee American College of Surgeons, Blake, Osgood.)

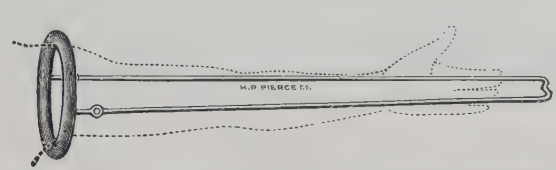


Fig. 289.—Murray-Jones arm splint for transportation. Jointed, permitting any angle of adjustment. Same as Fig. 288.

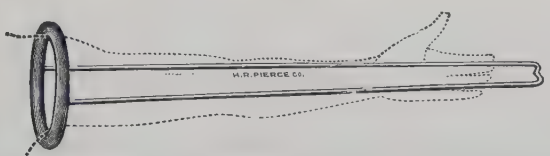


Fig. 290.—Jones' extension arm splint; serves either side. Made in two sizes of rings, 18 and 20 inches inside circumference.

The nearer the method of traction and suspension approaches the Hodgen principle of balanced suspension and traction from one point, the more ideal is the automatic adjustment (Lyle).

II. **Method by Weight Traction.**—The method by weight traction with the Thomas splint is the most ideal method of treating many fractures of the lower extremity. The application of the Thomas splint is the same as for fixed traction (see p. 212) excepting that instead of attaching the extension

Fig. 291.—Thomas arm splint hinged (Murray) for transportation, arm at side (after Sir Robert Jones).

straps to the lower end of the Thomas splint (fixed traction) they are attached to a spreader and cord and carried, as of old in Buck's extension (Fig. 286), over a pulley. This traction (mobile) is made by a turn around the end of the splint, Hodgen principle, or without the turn directly over the pulley attached to the foot of the bed or to the upright of the frame. The end of the splint may be fastened to the bed or upright of the frame and

Fig. 292.—Jones' arm splint applied. Note traction, suspending slings, abducted position—see Fig. 290 (after Sir Robert Jones).

traction made over the pulley. Countertraction may be made on the ring of the splint or through elevation of the foot of the bed by the patient's own body weight. The latter method is the preferable one. The conditions in each case will determine the most effective application of the forces of traction and countertraction.

If traction over a pulley is made on the limb with the lower end of the splint fixed and the foot of the bed elevated, the countertracting force against

the ischium will be somewhat advantageously modified so as to avoid undue pressure on the ischium by traction on the splint and by the patient's body weight (see Figs. 936, 1009).

The Knee Flexion Splint (Pearson).—To the principle of traction and suspension has been added the device in connection with the Thomas splint of the Pearson hinged knee flexion splint and a narrow foot piece. This may be purchased to fit any Thomas splint. Following traction or immobilization

Fig. 293.—Method of application of Thomas traction arm splint (Murray pattern) in fracture of the upper end of the humerus: Adhesive traction strips are applied to the upper arm, traction being obtained by weight and pulley. The arm is supported on flannel or canvas strips pinned to the side bars of the splint. The elbow may be flexed, as shown, and suspended by means of additional traction strips to an overhead frame; or it may be placed in the extended position, in which case only one pair of traction strips, extending from the wrist nearly to the axilla, is used. (M. G. H. Conference.)

or both combined in treating fracture of the lower limb, the very greatest difficulty is the prevention of stiffness of the knee-joint, or securing movement in the knee after stiffness has resulted. Traction on the leg is best made with the knee slightly flexed—25 to 30 degrees (see Fig. 286).

The Hodgen splint is made with a slight permanent angle at the knee (see Fig. 944).

By fastening the Pearson knee flexion splint to the upright of the Thomas splint an adjustable support for the leg is provided, which is of great value.

It is used for ideal traction purposes on the leg, for advantageous position in femur fractures, for exercise during extension treatment, for maintaining flexion position of the knee in fractures associated with lacerated wounds.

In fractures of the femur very little real immobilization is afforded by the Thomas splint excepting through the lateral bars and the supporting slings. The knee, of course, suffers more nearly complete immobilization. Pearson's hinged supplementary leg splint facilitates securing early motion at the knee (see Fig 286).

In slinging the Thomas splint when carrying the lower extremity it is important to provide for the support of the buttocks, particularly if the fracture is in the upper third of the femur (Hey-Groves). This is accomplished by the use of an air-cushion ring. The thickness of the cushion is about the thickness of a bed-pan, which permits the bed-pan being slipped into place without disturbing the position of the thigh. This cushion may not always be useful.

CHAPTER X

SKELETAL TRACTION—BONE TRACTION

Reason for skeletal traction—Instruments used—Places of application—Anesthetic—Preparation of the skin—Operation—Dressing—Weight—Duration of traction—Removal of instrument—Treatment of limb after removal of instrument—Subsequent course of wound—Removal of caliper—Thomas splint always with skeletal traction—Application to individual fractures—Advantages of direct bony traction—Objections to skeletal traction.

The applicability, the efficiency, and the simplicity of skeletal traction sufficiently recommend the method to the careful surgeon.

The use of skeletal traction was developed because of the proved inadequacy of other forms of traction. Traction by weight and pulley (1819), by adhesive plaster (1855), by the Hodgen splint (1860), by the use of the Thomas splint (1879)—all may prove to be inefficient where a heavy distracting force is necessary to overcome powerful muscular contraction and tense fascial retraction.

It appeared that the force applied directly to the bone was far more efficient than the indirect pull applied through the surface skin; not only was less weight necessary, but this smaller weight applied directly to the bone accomplished more rapidly and far more satisfactorily the desired result.

Several different instruments may be used to secure a hold on the bone. The ice tongs (Ransohoff) or caliper, the Codivilla or Steinman nail or pin, and the Finichetti stirrup are the usual instruments employed.

Direct bony traction requires less weight than skin traction, and yet if needed more weight can be used than is physically possible by means of skin traction. Bone traction is painless and continuous.

Places For the Application of Bone Traction.—The pin or caliper may be applied:

1. To the condyles of the femur.
2. To the upper end of the shaft of the tibia.
3. To the internal and external malleoli of the ankle.
4. To the os calcis or above the os calcis.
5. Through the olecranon.
6. To the condyles of the humerus.
7. To the lateral mass of the tibia.

(1) *The Condyles of the Femur.*—On the inner side a point is selected just above and in front of the adductor tubercle. And on the outer side a point is chosen in a more horizontal plane and directly in front of the iliotibial band (see Fig. 294). Caution: The synovial membrane of the knee-joint and the line of the epiphysis in children are to be carefully avoided (see Figs. 295–297).

(2) *The Upper End of the Shaft of the Tibia.*—The tibia is transfixed just below and behind the tubercle of the tibia. The tibial transfixion is

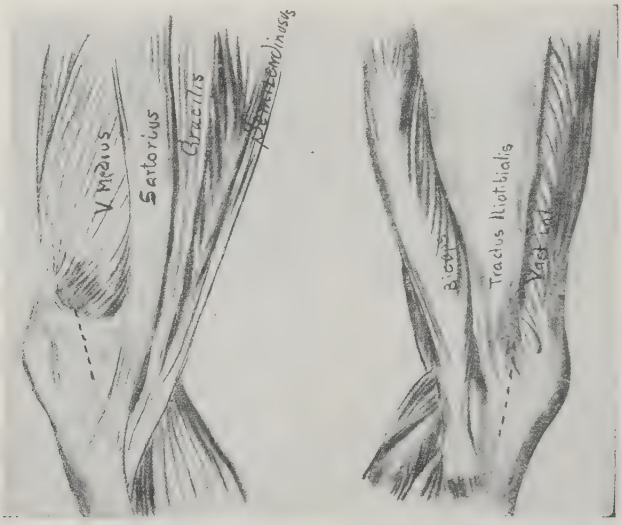


Fig. 294.—Dissection of the muscles and tendons on the inner and outer aspects of the lower end of the femur and the knee-joint. Note the respective levels of the vastus medialis and lateralis. The dotted line, made a bit straighter, indicates points of approach by incision to reach, when enlarged, the outer condyle of the femur and the inner side of the femoral shaft. (Thompson, Annals of Surgery, 1918.)

through avascular bone (see Fig. 298). It is superficial and not deep. Traction by tibial transfixion is directly at the insertions of the quadriceps and

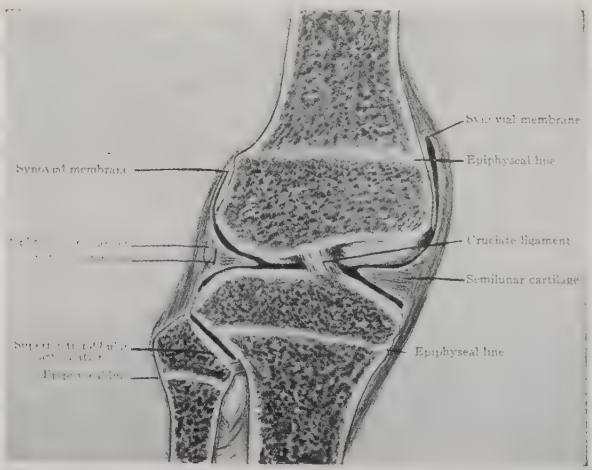


Fig. 295.—A coronal section through the knee-joint. The epiphyseal line of the tibia is extra-articular to the knee-joint. The epiphyseal line of the fibula is likewise extra-articular. The epiphyseal line of the femur is extra-articular on the outer side. On the inner side the synovial membrane of the knee-joint overlaps the epiphyseal line. (Thompson, Annals of Surgery, 1918.)

hamstring muscles. When tibial transfixion is employed the leg is placed in a position of flexion of both hip and knee and is suspended in a Hodgen or Thomas splint. Counterextension may be made by a perineal padded

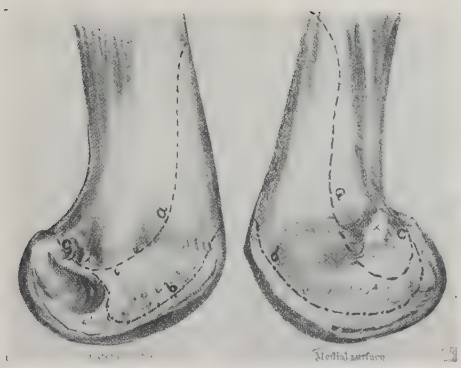


Fig. 296.—Lateral views of the distal extremity of the right femur. A cross marks each epicondyle. The line of attachment of the synovial membrane to the bone is shown by a dot and dash line, *b*; the line of reflection by the dotted line, *a* (Thompson).

Fig. 297.—The knee-joint distended with fluid. Note the contour and the extension in various directions of the capsular attachments to the bone. Note appropriate, because safe, place for attaching or inserting caliper or pin to femoral condyles (after Davis-Peotti).

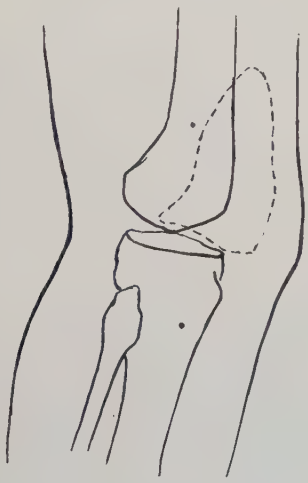


Fig. 298.—Skeletal traction. Note the carefully selected points for application of skeletal traction to condyles of femur (compare with Fig. 297) and of tibia (after Hey-Groves).

Fig. 299.—Skeletal traction. Note position of caliper on condyles of femur, if a rather anterior spot is chosen, in order to assist in elevation of upper end of lower fragment when fracture is supracondylar accompanied by ordinary displacement. In order to avoid the knee-joint capsule the caliper should be placed higher in the shaft than here indicated.

band on the sound side if necessary. This latter maneuver helps to secure abduction of the injured femur.

(3) *The Internal and External Malleoli of the Ankle.*—The exact spot for the application of the traction instrument, preferably a caliper, will be a bit above, ¼ inch, the real malleoli on the shafts of the bones. The points of the caliper must be made to penetrate the cortex so as to secure a firm hold. The fibula surface is comparatively narrow and in order to preclude the possibility of the caliper slipping great care should be used in the exact placing of the point of the instrument (see Fig. 309).

(4) *The Os Calcis.*—The most efficient skeletal traction in fractures below the knee is from the os calcis pin (see Figs. 306, 310, 311). The pin is put

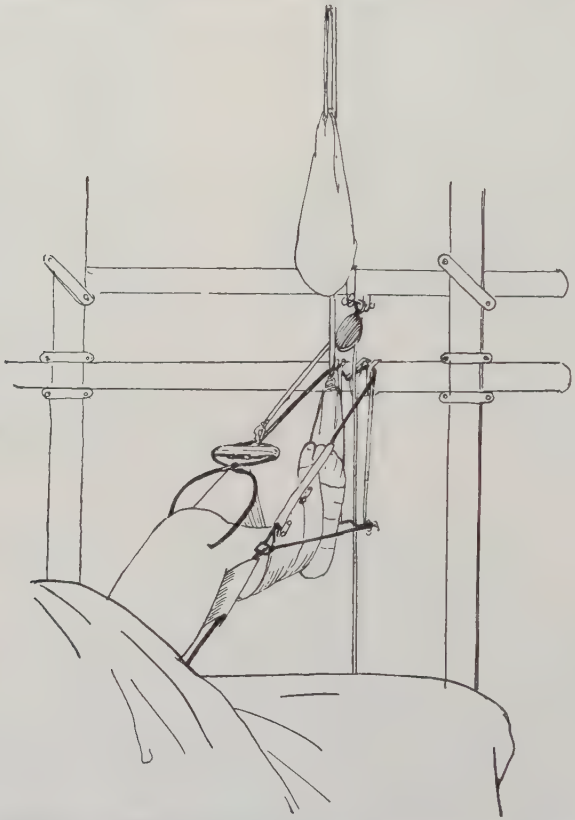


Fig. 300.—Skeletal traction in fractures of the femur: The points are introduced on a horizontal plane ½ inch (1.3 cm.) above and in front of the adductor tubercle. (M. G. H. Conference.)

through the bone from without inward at a point 1 inch behind and below the tip of the external malleolus (see Fig. 310). The position of the foot in external and internal rotation is under efficient control. It is thus possible to ascertain the extent and to adjust the rotation of the lower fragments of a fracture of the leg bones. A foot piece to the sole of the foot may be attached to the lateral traction rods.

The pin or nail should not be used in the os calcis of a child before the age of twelve or fourteen. There is but little solid bone in the os calcis before this time.

(5) *Through the Olecranon.*—Very occasionally fractures of the humerus will be most easily controlled by traction through a pin passed through the

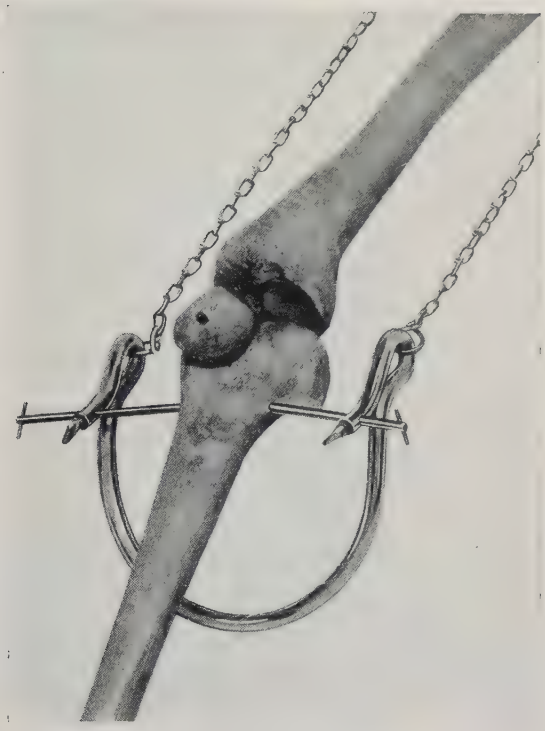


Fig. 301.—Langworthy's caliper for skeletal traction. This caliper was designed so that complete extension of the knee could be secured without interference from the caliper itself. It is shown here applied to the lower end of the femur. The two pins can be inserted to any depth in the bone. If desirable, they can be tapped in till they meet in the center, in which case the effect is the same as the Steinman pin. Extension is applied through two chains which go to a cross-bar below the foot. The weights are attached to this cross-bar. Thus no part of the caliper is in front of the knee-joint, leg, or foot, and complete uninterrupted extension as well as flexion of the knee is allowed.

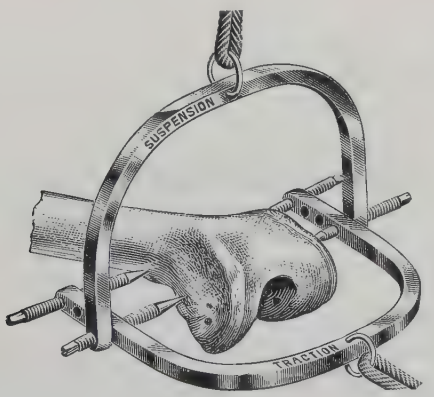


Fig. 302.—Hoglund traction and suspension tongs for supracondylar fractures of the femur.

olecranon process of the ulna (see Fig. 312). Such traction on a short $\frac{1}{8}$-inch pin is very effective.

(6) *To the Condyles of the Humerus.*—The application of a screw clamp for lateral pressure and traction (Hey-Groves) is valuable in certain fractures of the lower end of the humerus. The lateral pressure is controllable by a set nut. The tips of the pins may be finished with more than one point, thus securing a firmer hold in the bone (see Fig. 313).

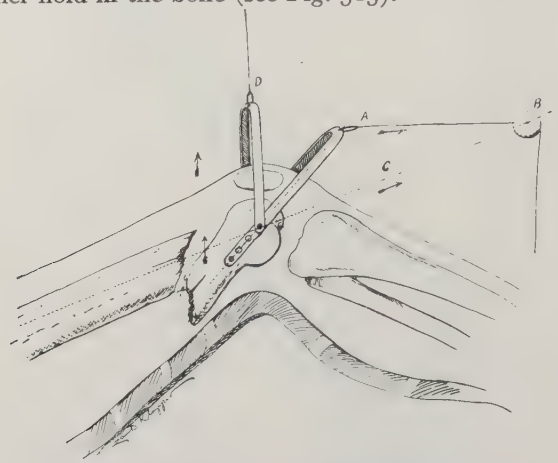


Fig. 303.—A schematic drawing showing application in a case of fracture of the femur of instrument seen in Fig. 302. The traction tongs with rope to pulley on rod *B* should be set so as to produce sufficient leverage to bring the bones in line, *C*. The suspension tongs with rope *D* are placed in a perpendicular position to act as a pivot. The limb may be placed in a Thomas splint with Pearson attachment for knee flexion. The screws as shown in Fig. 304 are one-half the diameter of the traction screws and are so constructed that they can be pushed through the soft tissues enabling the operator to feel for the shaft of the bone. It is wise to introduce the screw through a small skin incision. When the bone is located the thumb screw is screwed up into the frame of the tongs and the long screws tightened. The modification of the second screw as shown in Fig. 304 is not clearly shown in Fig. 302.

(7) *To the Lateral Masses of the Tibia.*—The same screw clamp is applicable to fractures of the upper end of the tibia, pressing together the already free fragments. Obviously, impacted fragments must be disengaged or broken apart—disimpacted—before this method can be efficient.

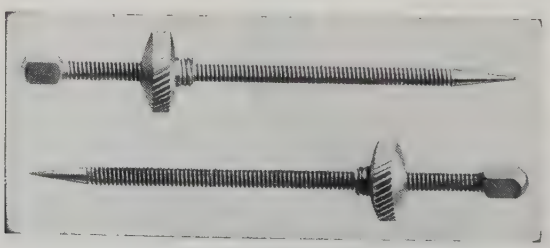


Fig. 304.—Screws used in the Hoglund apparatus, see Figs. 302, 303.

The pin or nail used in skeletal traction is about 8 inches long, 4 mm. in diameter, is of steel, sharpened at one end and blunt at the other end.

The Operation of Applying the Traction Pin or Caliper.—A general or local anesthetic may be used, which will depend entirely on the circumstances attending the case.

Preparation of the skin should be very carefully made as for any major

operation. This preparation should include the lower third of the thigh, the knee, and the upper third of the leg if the traction is to be made from the condyles of the femur. A wide area should be included in the local preparation wherever the traction is to be attached—whether the femoral condyle, tibial crest, or ankle malleoli.

The skin at the site of application of the pin or caliper should be pulled upward. A stab incision to the bone is made and slightly enlarged so that

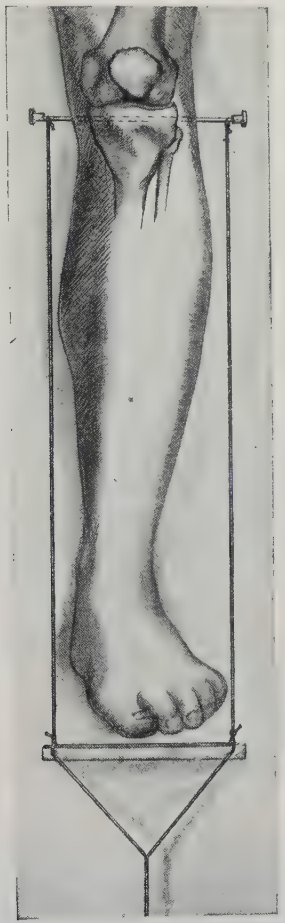


Fig. 305.—Steinmann's nail-extension apparatus employed in extension of the limb upon a horizontal plane, the pin being here shown passing transversely through the head of the tibia. The pin is better passed through the tibial crest—see Fig. 298. (From Bickham, Operative Surgery, vol. ii.)

the traction apparatus may rest eventually in the center of the short skin incision. The skin is then loose and free below the metal points.

The caliper point is inserted through the incision and driven into the cortex by a sharp light blow from the hammer. The skin is allowed to fall back into its natural position. As the pull is made on the caliper the skin incision is not impinged upon. The caliper should always be carefully inspected to see if it is working well.

Pain following the application and use of the caliper is ordinarily due to pressure on the skin by the steel instruments. If the instrument is properly applied there will be no pain.

If the Steinman nail is used the sharp-pointed pin is driven through the bone by a steel mallet. The opposite side away from the point of entrance is protected and supported by a thick small board covered with sterile towels. Against this firm support the pin can be driven into and through the bone readily. When the pin point reaches the skin of the opposite side it is exposed by a small skin incision as at the entrance point. Traction of the skin up-

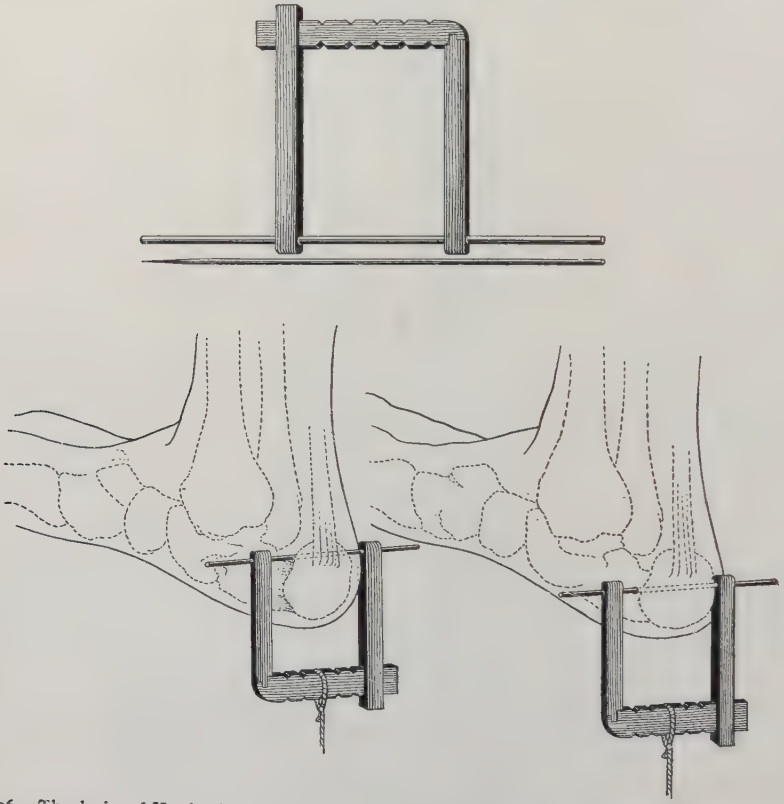


Fig. 306.—The device of Hawley in which a pin is passed over or through the os calcis. A substitute for the Finochietto-Chutro stirrup. (From Moorhead, Traumatic Surgery.)

ward is made as on the entrance side. The weight is attached to the caliper tongs or to the handles which fit the pin through the cord from the pulley at the foot of the bed (see Fig. 300).

The Dressing.—An occlusive dry dressing is very carefully applied and adjusted to each wound covering the adjacent skin for at least 6 inches on either side. Unless a wide area is dressed there is danger of infection from contiguous unprotected skin. Regular daily inspection of the security of the dressing will determine the frequency of change of dressing. I believe there is greater security in dressing such a wound frequently than at long inter-

vals. Each time the wounds are dressed the dressing should be conducted absolutely aseptically. The keeping of the wound absolutely dry will be

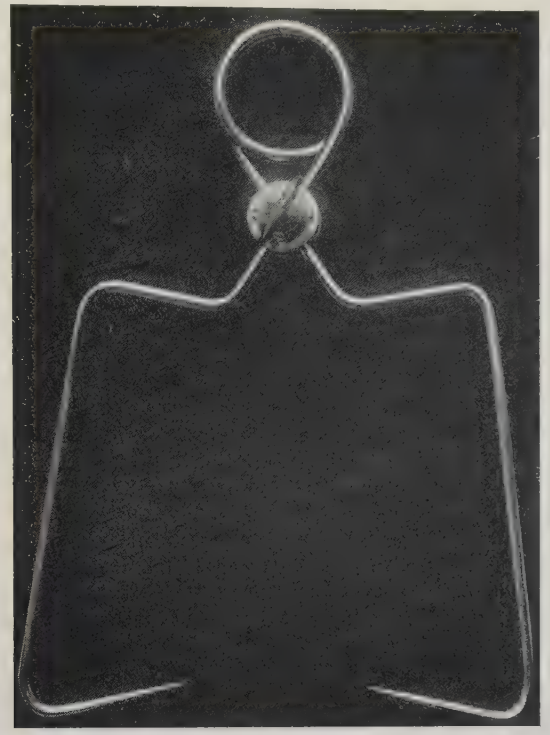


Fig. 307.—Professor Key, Stockholm, tongs for bony traction. Note the tongs are now open. Used at the Maria Hospital, Stockholm, Sweden. The lock nut of this model prevents divergence or convergence of the grasp of the tongs once applied. Tongs are made of one piece of metal so that the circular double loop spring forms the handle. It is constructed of non-rustible steel. The easy application of this model of tongs is an important consideration (Key-Thorndike).

conducive to sterility. Dry boric acid powder dusted on the wound after bathing the skin with 70 per cent. alcohol is satisfactorily combined with a dry sterile gauze dressing.

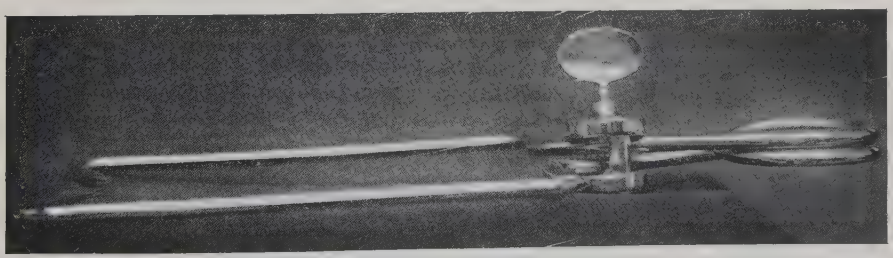


Fig. 308.—A detail of the lock nut is seen in this lateral view (Key-Thorndike).

Weight Necessary.—In recent fractures, within ten days, 10 or 15 pounds may be needed to bring the fragments of the femur or tibia into line. In older fractures, 15 to 30 pounds may be needed to accomplish this. In the

older fracture it may require from six to twelve days to secure the maximum traction effect.

Duration of Skeletal Traction.—Skeletal traction should be maintained until union of the fracture has definitely begun, possibly from four to eight weeks, and there is little or no danger of the slipping of the bone fragments following the removal of the traction.

Technic of Removal of the Pin and Caliper.—It is just as important to remove aseptically the pin and caliper from contact with the bone as it was to apply them aseptically in the beginning.

The Removal of the Pin.—The limb is supported as usual in its Thomas splint. The dressing is removed from the two lateral wounds. The weight is discontinued. The wound and parts about are thoroughly bathed with alcohol or benzine; the skin is touched with tincture of iodin, one-half strength

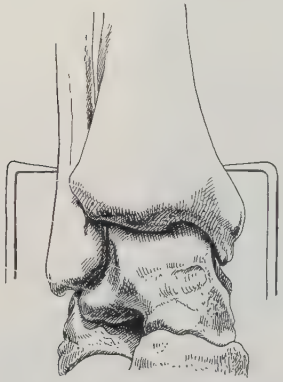


Fig. 309.—Skeletal traction. Note appropriate points of application of caliper to tibia and fibula at malleoli. If points for application are carefully selected and the insertion is guardedly made traction from the malleoli may be made effectively in certain fractures of the leg.

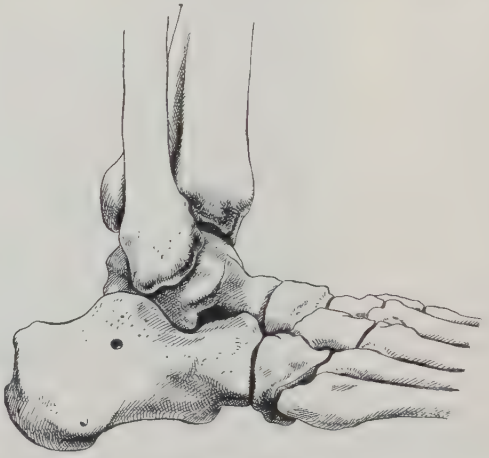


Fig. 310.—Skeletal traction. Note point of transfixion in os calcis, or place of application of the caliper.

U. S. P. The steel pin projecting from the wound on each side is wiped carefully with alcohol, 70 per cent., and completely covered with tincture of iodin. The limb is supported and the pin is gently but firmly pushed through the bone on one side, and as it reaches the wound it is pulled completely out. The wounds are bathed again, touched with tincture of iodin, and dressed aseptically with sterile gauze.

Subsequent Course of the Two Lateral Skeletal Traction Skin Wounds.—Ordinarily, a few drops of serum or puriform looking material will appear at each wound. Granulation tissue will close the openings. The epidermis will close the wound completely. The slight cicatrix will contract a bit, and eventually there will appear simply two tiny scars slightly dimpled and unattached to the underlying bone to mark the position of the traction pin. The appearances of the cicatrix and its exact location in cases of skeletal

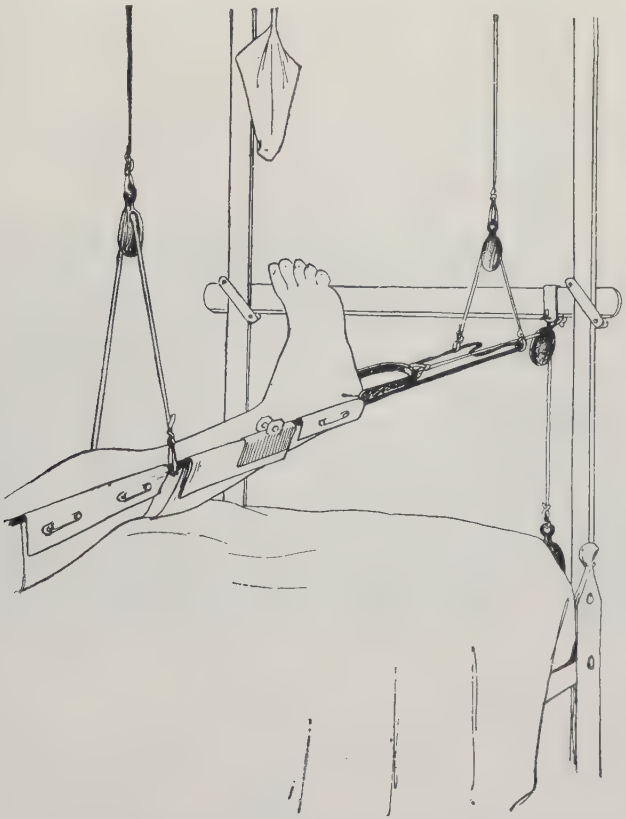


Fig. 311.—Skeletal traction on the os calcis: A Steinmann or similar steel pin is passed through the heel either over the top or through the os calcis. To this pin, by means of an appropriate clamp, traction by means of weight and pulley is attached, used in connection with the Thomas traction leg splint. (M. G. H. Confefence.)

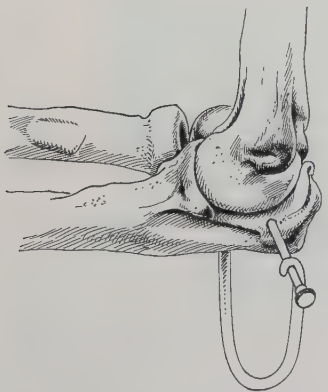


Fig. 312.—Skeletal traction. Extension in the humerus through transfixion of the olecranon of the ulna (after Hey-Groves-Aitken).

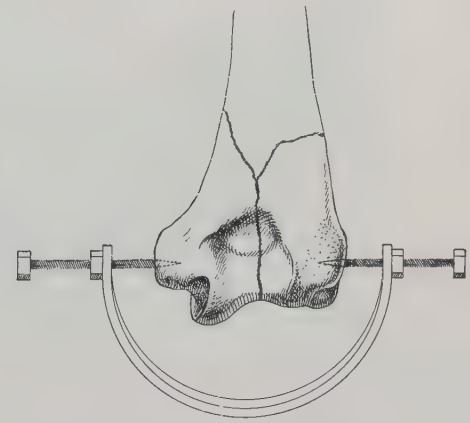


Fig. 313.—Note method of applying skeletal traction to condyles of the humerus. Instrument adjusted so as to exert lateral pressure as well as capable of being used for a direct longitudinal pull (after Hey-Groves).

traction to the condyles of the femur and to the os calcis are well exhibited in Figs. 314 to 319 inclusive.

Removal of the Caliper.—The same preparatory technic will be used as in the application of the caliper. The two calipers are lifted out of the wounds on opposite sides. Otherwise, the procedure is similar to that followed in the removal of the Steinmann nail.

Fig. 314.—Skeletal traction. Note the slight cicatrices, indicated by pointers, where calipers were applied in making traction on the condyles of the femur in a case of fracture of the shaft of the femur. Note active flexion of the knee-joint following femur fracture (Conwell).

After Removal of the Skeletal Traction.—The treatment of the fracture after the removal of the traction instrument will depend on the part concerned and will be considered under the femur and the tibia. In general it may be said that the continuance of the support of the fracture will be necessary and wise for a time in the suspended Thomas splint.

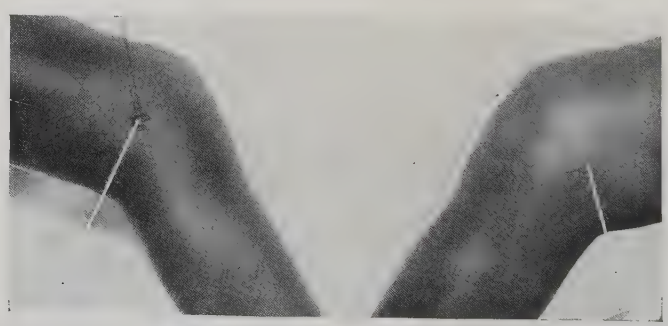


Fig. 315.—Skeletal traction. Note the slight cicatrices on either side of the knee indicated by pointers where calipers were inserted in using traction to the condyles of the femur (Conwell).

Bony traction will be combined most advantageously with the Thomas suspension splint and ordinarily with the Pearson hinged leg attachment. The leather ring of the Thomas splint is suspended from the Balkan frame by sufficient weight and at such an angle as to keep the ring in contact with the ischium. The lower end of the splint is fixed to the foot of the bed or up-

right. The direct pull of the weight acts through the cord over a pulley on the upright of the Balkan frame. With the traction and countertraction

Fig. 316.—Fracture of the shaft of the femur. Caliper traction. Caliper cicatrix *a* on the outer side of thigh. Note slight cicatrix, flexion of knee following this injury. Note the site of caliper insertion (Conwell).

great care must be taken of the perineum and ischial region to prevent undue pressure.

For application of bony traction to individual fractures see fractures of the femur and fractures of the tibia.

Fig. 317.—Fracture of shaft of the femur. Skeletal caliper traction. Note small cicatrix *b* from caliper on the inner side of thigh near knee. Same case as Fig. 316. Note flexion of knee following this injury. Note position of caliper insertion (Conwell).

Advantages of Direct Bony Traction.—(*a*) It is a mechanically sound method. Experience has proved that good alignment can be secured with uniformity.

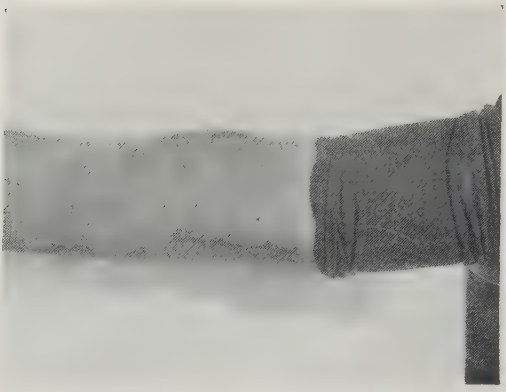


Fig. 318.—Fracture of shaft of the femur. Skeletal caliper traction. Note small cicatrix remaining locating site of application of caliper on the outer side of thigh near knee. Same case as Figs. 316, 317. Note complete extension of the knee following this injury (Conwell).

Fig. 319.—Skeletal traction. Compound comminuted fracture of both bones of the leg. A pin was used through the os calcis. The pin has been removed. Note the exact points that the pin emerged from the os calcis on outer and inner sides of foot. The arrows point to the cicatrices of wounds made by the pin (Conwell).

(*b*) The knee-joint is free for active and passive movements.

(*c*) The ligaments of the knee are not strained by traction.

(*d*) The entire limb is free for inspection and for massage and for adjustments.

(*e*) It can be used when wounds of the thigh or leg are present, leaving these wounds accessible for frequent dressings, as in certain compound fractures.

(*f*) The axis of traction may be altered easily to suit the conditions of the fracture.

(*g*) The institution of skeletal traction should be regarded as an operative procedure demanding intelligent judgment and surgical skill. If judgment and skill are exercised in this operative procedure no untoward symptoms will arise.

(*h*) It is a safe procedure.

(*i*) With the limb supported in a suspended Thomas splint with the Pearson hinged leg support early passive and active movement of the knee-joint is possible, practicable, and profitable.

Objections to Skeletal Traction.—Sepsis may start in the skin wound and spread to the bone extending to the adjacent joint; this joint becoming septic, amputation of the thigh may be necessary. This disaster has happened. It is preventable—should never happen. Any superficial infection in the skin wound is amenable to treatment, and if it occurs is usually of a mild grade.

Persistent discharging sinuses are said to have followed skeletal traction, possibly associated also with some localized osteomyelitis. This is possible, but very rare.

The nail may break. The caliper may slip or creep on the bone. The capsule of the joint may be opened. The epiphyseal line may be disturbed. The bone (os calcis) may be slowly cut through by the pin. All these things have happened, but not where surgical asepsis, judgment, and caution have been exercised.

None of these objections should militate against the proper employment of bone traction when it is indicated.

CHAPTER XI

FRACTURES OF THE HUMERUS

FRACTURES OF THE UPPER END OF THE HUMERUS

Anatomy—Examination of the shoulder—Possible lesions—First aid—Dislocation of head—Fracture of anatomical neck—Separation of the upper epiphysis—Fracture of the surgical neck—Fracture of the great tuberosity—Fracture of the lesser tuberosity—Fractures with little displacement—Fractures with much displacement—Abduction, external rotation, bed traction—Suspension—Prognosis—Operative treatment—Fracture of upper end of humerus with dislocation of the head—Excision of the shoulder for fracture.

Anatomy.—The clavicle may be felt throughout its entire length from sternum to acromion. The acromial process of the scapula articulates with the outer end of the clavicle. This acromioclavicular joint has an anteroposterior direction, and if the line of this joint is continued anteriorly it

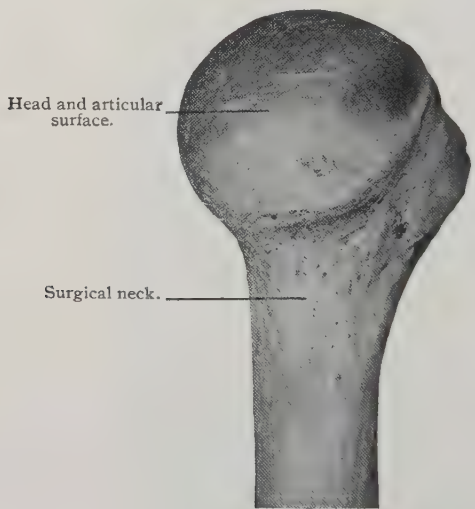


Fig. 320.—Upper end of humerus. Inner view.

will pass down the front of the upper arm (see Fig. 324). The outer edge of the acromion is continuous downward and backward with the spine of the scapula. The great tuberosity of the humerus projects beyond the acromial process, and is covered by the deltoid muscle. The point of the shoulder itself is made by the humerus and not by the acromion (Figs. 324, 327, 328).

Examination of the Shoulder.—The uninjured shoulder should be examined before the injured shoulder. In injuries doubtful in character, associated with much swelling of the shoulder, and which are painful upon

gentle manipulation, the examination should be made with the aid of an anesthetic. Great swelling suggests great trauma; absence of all swelling appreciable to the eye suggests slight trauma.

Fig. 321.—Illustrating the site of a fracture through the anatomical neck of the humerus (after Davis-Peotti).

Fig. 322.—A fracture separating the upper humeral epiphysis. The pull of the supraspinatus is well shown (after Davis-Peotti).

For the examination the patient should be seated upon a rather high stool, so that the shoulder comes to an easy level for manipulation. The shoulder should be grasped, so that the head of the humerus can be felt

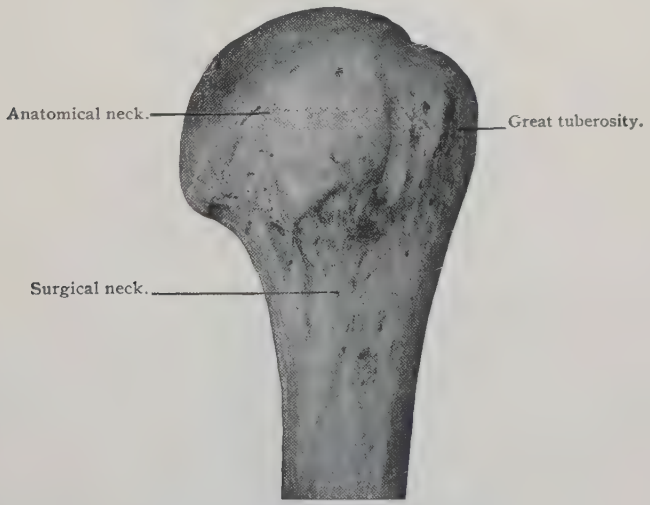


Fig. 323.—Upper end of humerus. Anterior view.

between the fingers and thumb of one hand pressed under the spinous and acromial processes. The other hand should grasp the flexed elbow firmly in order to make the necessary movements at the shoulder-joint (Fig. 329).

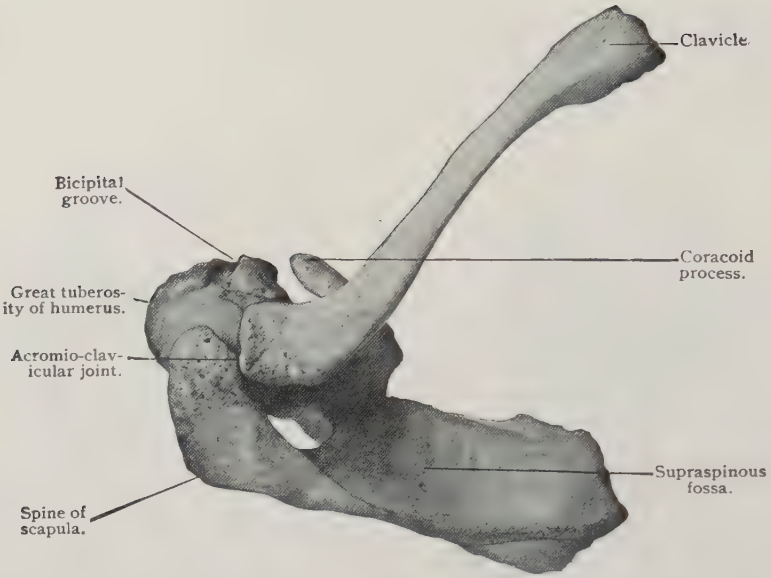


Fig. 324.—View of bones of the shoulder from above. Notice acromioclavicular joint, its relations to the bicipital groove and coracoid process. The point of the shoulder is made by the great tuberosity of the humerus.

Fig. 325.—Drawing to show the shoulder-joint ligaments, acromioclavicular and the coracoclavicular ligaments. Note the tendon of the supraspinatus, the coracoid process, coracobrachialis muscle, the short head of the biceps, long head of the biceps, the pectoralis major muscle (after Davis-Peotti).

If the head of the humerus is intact and in its normal place, it will be felt to move with the shaft of the humerus, as upon the uninjured side. All

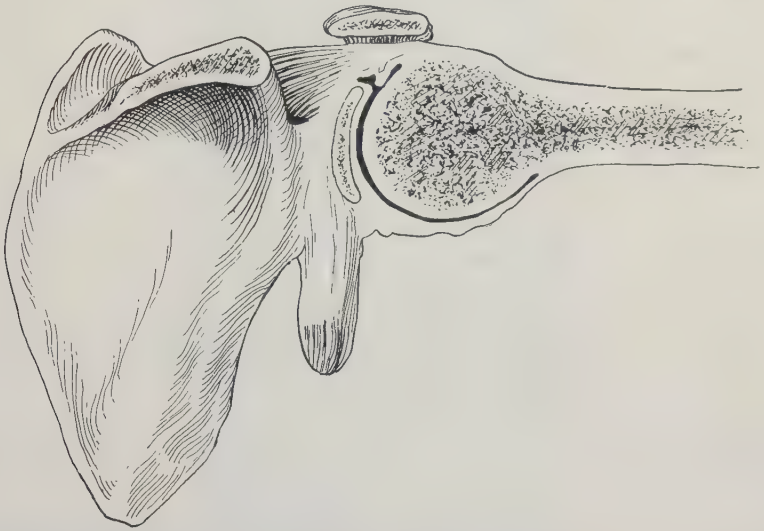


Fig. 326.—A diagram of a frontal section passing through the shoulder-joint with the arm in abduction. Note the attachment of the capsule and how taut it lies in this abducted position. Note spine of scapula, acromion process, glenoid process, long head of the triceps cut. Compare with Fig. 327 (after Davis-Peotti).

the normal movements of the shoulder-joint should be made passively and actively—namely, the movements of abduction, adduction, forward and

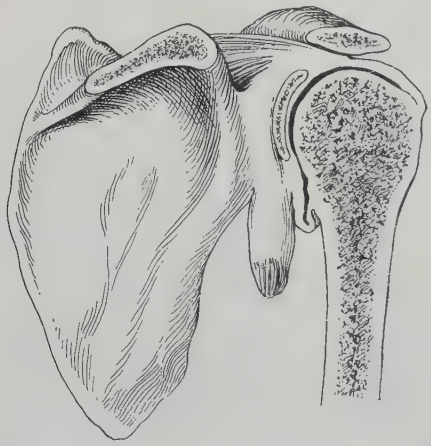


Fig. 327.—A diagram of a frontal section of the shoulder-joint while the arm is in adduction at the side. Note the relaxed condition of the shoulder-joint capsule on the inferior surface of the joint. Compare with Fig. 326 (after Davis-Peotti).

backward swing, and rotation (Figs. 330–332). Those movements which are painful and limited should be carefully noted. Unless the normal individual standard of movement is known, as determined by examination

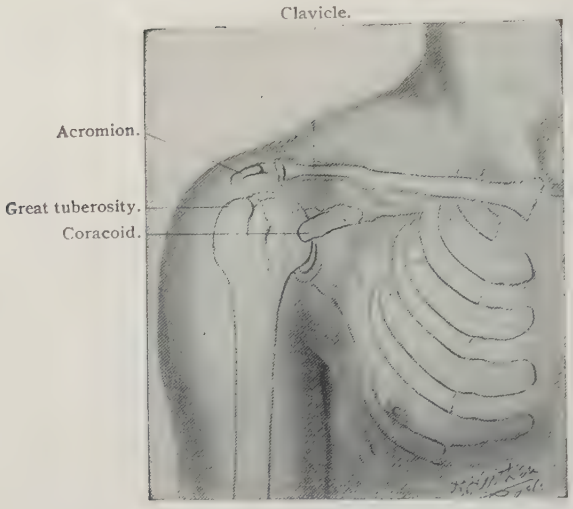


Fig. 328.—Relations of bones to surfaces of shoulder region. Great tuberosity of humerus projects beyond the acromial process of scapula. Relations of coracoid to clavicle and head of humerus (compare with Figs. 329, 334).

Fig. 329.—Examination of shoulder. Method of palpating head of humerus with thumb and fingers. Elbow grasped by other hand.

Fig. 330.—Examination of shoulder. Movements of the shoulder. Normal maximum abduction. Notice method of grasping head of humerus.

of the well shoulder, there can be no definite interpretation of the conditions existing in the injured shoulder. The condition of the circulation and the presence of paresis or paralysis in the limb should be observed. The shaft

Fig. 331.—Examination of shoulder. Maximum adduction. The bend of the elbow, when the forearm is flexed to a right angle, comes to the median line of trunk.

Fig. 332.—Examination of shoulder. Maximum outward rotation. Notice position of examining hands.

of the humerus should be measured; the measurement best taken is the distance between the edge of the acromial process and the external condyle of the humerus. The patient should be seated with the elbow at the side if possible, and flexed to a right angle (Fig. 333). The forearm should rest on the thigh of the same side. The direction of the long axis of the humerus should be carefully noted.

The coracoid process of the scapula in all injuries to the shoulder should be palpated, for a knowledge of its position assists in locating the head of the humerus intelligently (Fig. 334). The examiner should stand in front of the patient, and place the left hand upon the right shoulder and the right hand upon the left shoulder, the hands being open. The thumb should fall below the clavicle a full fingerbreadth, when the end of the thumb will touch

Fig. 333.—Method of measuring the length of the shaft of the humerus from the acromial process to the external condyle.

Fig. 334.—Examination of shoulder. Palpating the coracoid processes. Note the position of the hands and thumbs.

the coracoid. It is generally possible to feel the coracoid even in very stout people and when much swelling is present.

The shoulder-joint possesses a very great range of movement. This range is of value in the ordinary pursuits of daily life. If any degree of the normal movement is limited the disability is often considerable.

Diagnosis.—It is sometimes impossible to determine the exact lesion following an injury to the shoulder from the physical examination without Roentgen rays. Roentgen ray stereoscopic plates are absolutely essential in every injury to the shoulder, whether the force has been excessive or mild, that an exact diagnosis may be made. It is of the first importance to know whether the head of the humerus is in the glenoid cavity or whether it is dislocated; this is determined by palpation and by noting the direction of the

long axis of the humerus. It is next in importance to learn whether there is a fracture of the humerus. If the humeral head rotates with the shaft, there is probably no fracture unless there is one with impaction or one of the great tuberosity. If the humeral head does not rotate with the shaft, then there is a fracture. If crepitus is present, the diagnosis is confirmed. In elderly people a simple contusion of the shoulder from a fall may occasion so great a hematoma without any other damage that one may be in considerable doubt whether or not a fracture exists. The vessels in the aged

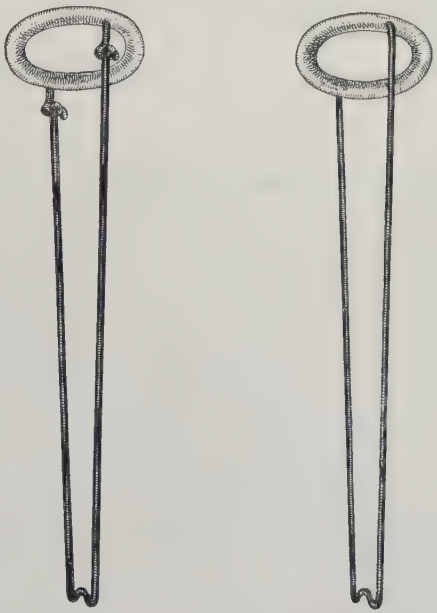


Fig. 335.—The hinged traction arm splint (Murray) and the Thomas traction arm splint. The hinged splint should be used for transportation and is also to be preferred for treatment. Used for injuries of the shoulder, arm, elbow, and forearm (Blake).

are easily lacerated and great extravasations may occur and be very misleading. After injury to the shoulder the following fracture lesions may be present, and are to be considered:

Fracture of the anatomical neck of the humerus.
Separation of the upper humeral epiphysis.
Fracture of the surgical neck of the humerus.
Fracture of the great tuberosity of the humerus.
Fracture of the glenoid of the scapula.

In any one of these instances a dislocation of the humeral head from the glenoid cavity may exist and complicate the case.

Emergency First-aid Treatment.—Following an injury to the shoulder or upper arm it may be that placing the forearm in a sling will be the quickest, simplest, and best temporary dressing. Possibly placing a swathe about the injured arm and body may further steady the injured part.

If it is possible to use a modified Thomas splint, shown in Fig. 335, it will be found to be comfortable and suitable for transportation. It may likewise be used for the permanent dressing. Its method of application is

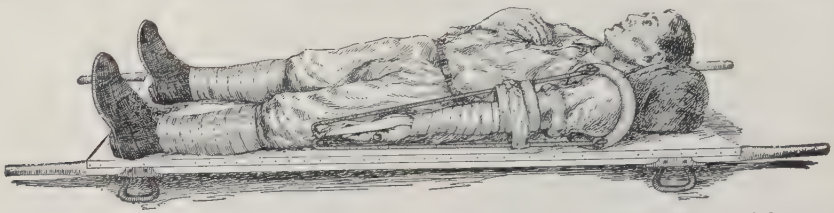


Fig. 336.—Application of the Thomas hinged arm splint (Murray) for transportation of fractures of the humerus. Note the method of slinging the arm in the splint. Traction is made by adhesive applied to the forearm and tied over the end of the splint. On account of the slight traction requisite in these fractures, the Spanish windlass is seldom necessary (Blake).

seen in Figs. 291 and 336. Every surgeon likely to have to care for such accidents should have two such splints always available for emergencies.

Simple Dislocation of the Humeral Head, Subcoracoid (Fig. 337).—The attitude is characteristic: the affected arm is held flexed, with the elbow

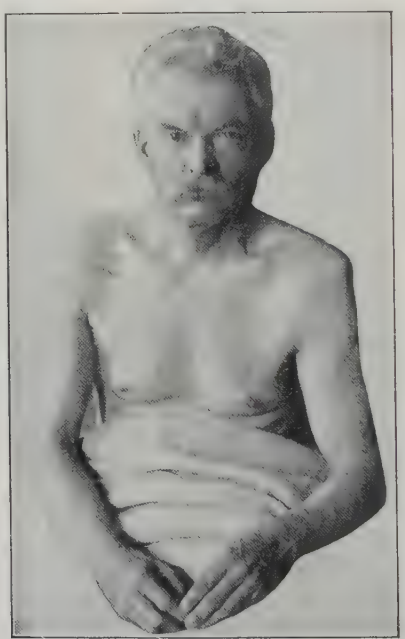


Fig. 337.—Dislocation of the left shoulder. Note the flat deltoid. Prominence under coracoid. Direction of the long axis of the humeral shaft. Lengthening of upper arm. Left nipple lowered. Anterior axillary fold lowered.

away from the side and the arm rotated inward. The anterior axillary fold is lowered upon the injured side. The long axis of the shaft of the humerus is inclined inward. The roundness of the shoulder is flattened. The acromial process is prominent. The head of the humerus is out of the glenoid cavity, and most often lies under the coracoid process. The elbow cannot be brought

in front toward the median line, nor can the hand of the injured arm be placed upon the opposite shoulder. Active and passive movements at the shoulder-joint are greatly restricted. Measuring from the acromial process to the external epicondyle of the humerus, the upper arm, in a subcoracoid dislocation, is lengthened. A soft crepitation may be detected in manipulating the shoulder, which simulates bony crepitus.

Fracture of the Anatomical Neck (Figs. 338–341).—This occurs in elderly people. It is often overlooked. Swelling of the shoulder is evident. Anesthesia is often necessary for a careful examination with deep palpation. There is thickening of the neck of the bone. Crepitus will be felt unless the fracture is impacted. There will be pain upon moving the shoulder. Ab-

Fig. 338.—Fracture of the anatomical neck of the left humerus. Atrophy of the shoulder muscles. Deformity at the seat of the fracture, seen a little below acromial process upon the anterior surface of the shoulder just inside the white line.

normal mobility may be felt high up the shaft close to the head of the bone. This fracture lies wholly within the capsule of the joint or within its attachment to the humerus.

I am inclined to think that this fracture impacted is far more common than is generally supposed, particularly in middle-aged and elderly people.

It is often unrecognized, the patient being told that he has a bruised shoulder and that pain and limitation of motion will disappear shortly.

Such patients complain of persistent pain about the shoulder-joint, limitation of motion in the extremes of shoulder-joint movements, rarely joint tenderness to pressure. "The shoulder doesn't feel right" is often stated. A carefully taken *x*-ray will disclose a fracture of the anatomical neck of the humerus with some little impaction of the bone.

The treatment of such an impacted fracture will be largely symptomatic. Use of the joint early and within the limits of persistent after-pain will be

Fig. 339.—Normal right shoulder. Compare with Fig. 340.

Fig. 340.—Fracture of the anatomical neck of the left humerus. Sharp deformity anteriorly characteristic. Compare with Figs. 338 and 339.

Fig. 341.—Fracture of the anatomical neck of the humerus (M. G. H. series). Note changed relations of articular surface of humerus and shaft of humerus.

proper. Moist heat to the shoulder will relieve the pain and ache in such a shoulder better than almost anything. If the arm feels heavy and uncomfortable it should be supported by a properly adjusted sling. This fracture has

its counterpart in old people in the rather unusual impacted fracture of the neck of the femur. This fracture of the humerus occurs in adult life, and may happen from slight trauma, and is rather tedious in recovery.

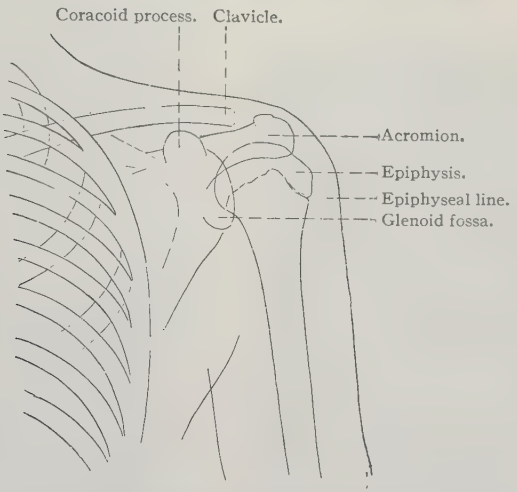


Fig. 342.—Normal shoulder, showing epiphysis of upper end of humerus (*x*-ray tracing).

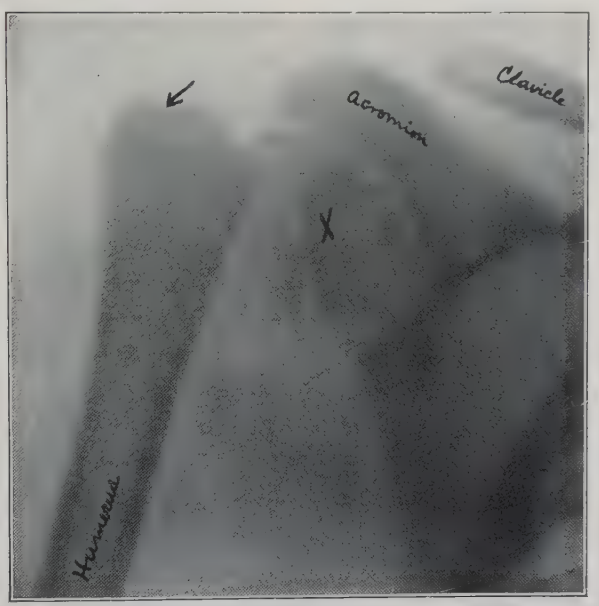


Fig. 343.—Separation of the upper epiphysis of the humerus. Incision facilitated accurate reduction. Reduction maintained by abduction and slight rotation outward of the arm. Arrow points to upper end of shaft of humerus. X is on the head of the bone articulating with the glenoid, but abnormally placed as compared with its fellow, the shaft.

Separation of the Upper Epiphysis (Figs. 342–347).—The separation of the upper humeral epiphysis will not necessarily open the joint cavity, for the capsular ligament is firmly attached to the epiphysis and the synovial

Fig. 344.—Separation of upper epiphysis of the humerus immediately after the accident. Note, especially, position of upper arm and position of head, and deep crease in skin made by the catching of the skin in the upper end of the lower fragment. Same as Fig. 345.

Fig. 345.—Separation of the upper epiphysis of the humerus (left). Notice shortening of the upper arm. Unusual fulness internal and above normal position for head. Same as Fig. 346. White line points to deformity.

Fig. 346.—Separation of the upper epiphysis of the left humerus. Notice prominence below normal place for humeral head. This prominence is made by the upper end of lower fragment. Same case as Fig. 344. White line marks deformity.

membrane is but loosely attached to the diaphysis. The line of the separation of the upper epiphysis of the humerus begins on the inner side of the head of the bone and runs across almost horizontally, rising toward the center

of the shaft, and ends in the outer side of the bone, so that the epiphysis includes the tuberosities.

This happens to young people, but never before the sixth year and never after the twentieth year. The most frequent period is between the ages of nine and seventeen years. Ordinarily, the upper end of the lower fragment projects forward and inward, producing a characteristic deformity. This injury may occur either with or without displacement of the shaft of the bone, depending upon the force causing the injury and upon the muscular pull. The signs are a little like those attending a fracture of the surgical neck of the humerus. There may be no displacement at first and after a few (three) days a distinct displacement appears, especially if no attempt is

Fig. 347.—Roentgenogram of a fracture through the high surgical neck of the humerus. Note rotation of proximal fragment in abduction, and position of upper end of distal fragment beneath glenoid in axilla (Healey).

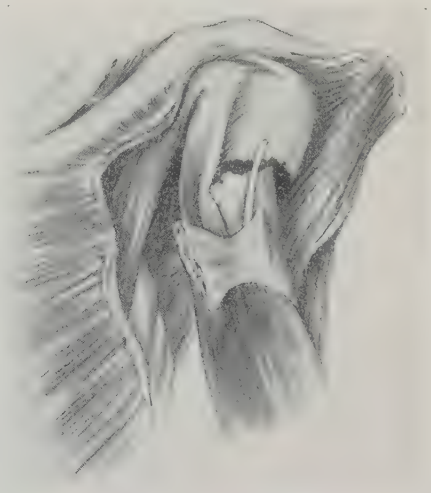


Fig. 348.—Fracture of the surgical neck of the humerus. The displacement of the upper fragment is due to the contraction of the supraspinatus muscle. The lower fragment is pulled inward by the combined action of the pectoralis major, latissimus dorsi, and the teres major. The arm is somewhat abducted by the deltoid (after Davis-Peotti).

made to hold the shoulder still. The displacement may be partial or complete. Partial displacement is more common than complete. The head of the bone is in the glenoid fossa, but rotated by the muscles attached to it so that its articular surface looks downward. It does not rotate with the shaft. The crepitus is of a softer quality than in cases of fracture—*i. e.*, cartilaginous. Localized pain and swelling are present. A puckering of the skin, caused by the hooking of the lower fragment into the skin, is characteristic (see Fig. 344). Palpation reveals the upper end of the shaft as a comparatively smooth surface, unlike the end of a fractured bone. The shoulder maintains its rounder natural appearance. Grasping the head of the humerus, angular movement of the humeral shaft will fail to move the head, whereas rotatory movement may move it. An absence of shortening of the upper arm means

absence of great displacement and untorn periosteum. A high lesion near the joint in a young patient, showing displacement forward and inward of the shaft, is very suggestive of epiphyseal separation.

Treatment of Separation of the Upper Epiphysis of the Humerus.—When there is no displacement, immobilization of the shoulder-joint is indicated by body and upper arm swathe and cravat sling to forearm.

When there is but slight displacement, firm pressure with traction will ordinarily correct the deformity.

When there is much displacement, reduction is often not only hard to effect, but sometimes impossible without operative assistance.

Fig. 349.—Fracture of the shaft of the humerus below the insertion of the deltoid. Note the displacement of the upper fragment in abduction through contraction of the deltoid. Note infraspinatus, teres minor, teres major, latissimus dorsi, long head of the triceps, and external head of the triceps (after Davis-Peotti).

In youngsters the epiphyseal line or surface is more or less rounded or conical, consequently it is relatively easy to hold a displaced epiphysis reduced, but in an older child this same epiphyseal surface is more nearly a horizontal plane and it is difficult to keep reduced such a separation.

The chief obstacle to reduction is the position assumed by the upper fragment. The muscles attached to the tuberosity draw the upper fragment forward and outward so that the humeral articular surface looks downward. Attention is called to the fact that placing the lower fragment in

line with the displaced upper fragment, that is, abducting the upper arm, will permit of reduction. Figure 370 shows the abducted position maintained by a plaster-of-Paris splint, but without external rotation.

I have found that when it is impossible to secure reduction by the use of traction and this position, that an incision over the shoulder longitudinally with the deltoid fibers and separation of these fibers will enable the finger to be introduced to the seat of fracture, then intelligent traction and abduction, together with slight external or internal rotation of the shaft, will reduce the fracture. It is important to put the arm up in that degree of abduction which it is found, with the wound open, will best maintain reduction. It may be necessary to vary the angle and, at times, to put the arm up in extreme adduction or swung forward.

Other obstacles to reduction are the capsule of the joint, the bands of the periosteum or fascia, or the muscles or tendon of the long head of the biceps caught between the fragments. In operating it will almost never be necessary to resect the head of the bone. In almost no instance can it be determined before operating exactly what procedure will be followed or what position will be the permanent position for healing.

Fig. 350.—Roentgenogram of fracture of the shaft of the humerus, a low surgical neck fracture without lateral displacement (Holmes).

Fig. 351.—Fracture of the shaft of the humerus above the insertion of the deltoid muscle. The lower fragment is drawn slightly outward by the deltoid. The upper fragment is drawn inward by the pectoralis major, latissimus dorsi, and teres major, which see in drawing. Note the long and short heads of the biceps, the deltoid, and the brachialis anticus muscles (after Davis-Peotti).

Prognosis.—Usually union occurs if there is no displacement or only slight displacement, without deformity and with a functionally useful shoulder. If there is great displacement, deformity and impairment of motion will persist if reduction is not complete. The growth of the humerus may be interfered with if an unreduced epiphyseal displacement is allowed to remain untreated. Compensation will undoubtedly occur in the growing child if deformity is not completely corrected.

Fracture of the Surgical Neck (Figs. 350–354).—Any fracture below the epiphyseal line of the upper end of the humerus and well within the

upper fourth of the shaft of the bone to the insertions of the pectoralis major and the latissimus dorsi muscles may be regarded, for all practical purposes,

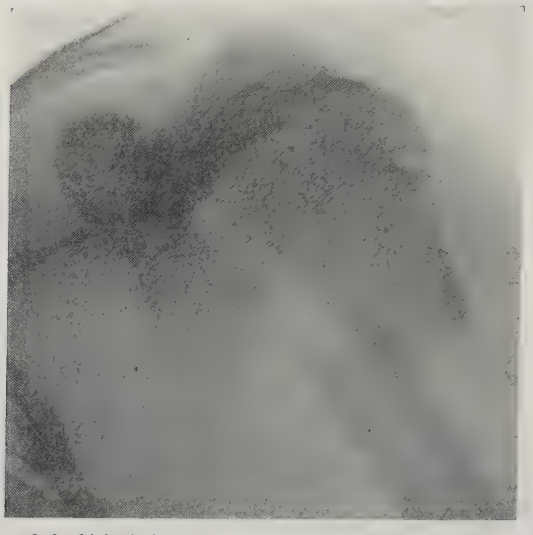


Fig. 352.—Fracture of the high shaft of the humerus. Note displacement. This fracture if immediately treated by heavy traction in recumbent position and suspension of upper extremity (see Figs. 372, 373) probably could be replaced. In this instance an incision and leverage without internal suture was used successfully.

as a fracture of the surgical neck of the humerus. Fracture of the surgical neck is the common fracture of the upper end of the humerus. Fracture of

Fig. 353.—Fracture of the high surgical neck of the humerus, unilateral impaction. Note rotation of the head and displacement of the upper end of shaft of humerus (Dodd).

the anatomical neck is most often seen in the aged. Separation of the upper humeral epiphysis occurs in youth.

The head of the bone is found in the glenoid cavity. Passive movements are associated with pain and elicit crepitus and abnormal mobility at the seat of fracture, provided, of course, the fracture is not impacted. The arm is slightly shortened. The arm is held flexed with the elbow at the side.

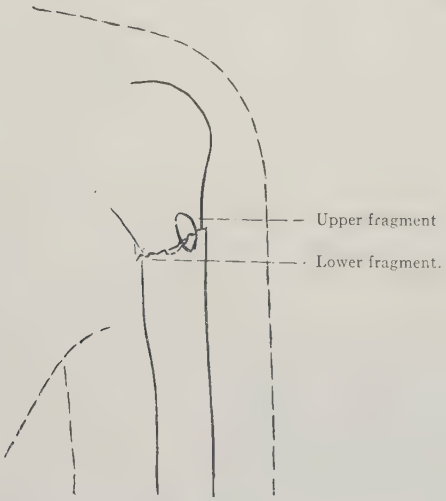


Fig. 354.—Fracture of surgical neck of the humerus, after reduction by open incision and wiring with silver wire. Recovery as to motion complete (*x*-ray tracing) (Eliot). A suture of chromic catgut No. 2 scale might replace the wire suture advantageously. Avoid non-absorbable sutures when possible.

Following fracture of the surgical neck displacements of the fragments will occur somewhat as follows: The upper fragment abducted and externally rotated, the lower fragment displaced upward (arm shortened) and inwardly rotated. The shortening of the arm due to the upward displacement of the

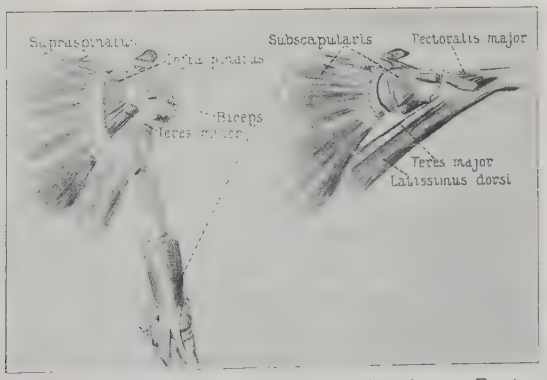


Fig. 355.—Note muscle pull and reposition of fragments in abduction of arm. Fracture of the surgical neck of the humerus (Henderson).

lower fragment may bring the upper end of this fragment clear up to the glenoid cavity. The presence of the sharp upper end of the lower shaft fragment close to the axillary vessels suggests gentle and intelligent handling of this injury.

Continuance of the violence of the accident and muscle contraction and fascial retraction combine to bring about these characteristic displacements, which are quite common. If after an injury to the shoulder no positive gross evidences of fracture or dislocation exist, and there are tenderness and localized swelling about the joint, and motion is painful, it is more probable that some bony lesion exists than that a simple contusion is present.

Subperiosteal Fracture of the Upper End of the Humerus in Children.—J. S. Stone has called especial attention to a group of subperiosteal fractures of the upper end of the humerus occurring in young children from six to fourteen years of age.

The injury is received by a fall upon the outstretched hand and is followed by more or less complete inability to abduct the elbow from the side. The deltoid seems partly paralyzed. There will be detected slight muscle spasm about the shoulder in recent cases and tenderness high up on the shaft of the humerus. There will be slight pain about the shoulder. Crepitus and abnormal mobility will be absent. An *x*-ray will confirm the diagnosis in these somewhat blind cases. Of course, the line cannot be sharply drawn between this group of subperiosteal fractures and those instances of fracture in the same region attended by slight displacement or impaction not subperiosteal. The important fact to be kept always in mind is that children suffering from disability of the shoulder of an indefinite sort as determined by casual examination should be examined with extreme caution in order to detect if possible a subperiosteal fracture of the upper end of the humerus. The prognosis and treatment will be far more definite and satisfactory if the exact lesion is determined.

Fracture of the Greater Tuberosity of the Humerus.—This fracture should be regarded as a major injury because of the very considerable disability which may follow it.

Greater tuberosity fracture may result from either a fall upon the shoulder or from extreme abduction of the upper arm. It may occur either alone or associated with a dislocation of the upper end of the humerus. The fracture with most marked displacement occurs with a subglenoid dislocation. If, after the reduction of a dislocation of the shoulder, disability continues longer than usual following simple dislocation, suspicion should be aroused that there may have been a fracture of the greater tuberosity which has been overlooked in the original *x*-ray associated with the dislocation. A stereoscopic *x*-ray will make the diagnosis positive. The roentgenogram should be made with the arm slightly adducted and outwardly rotated. In this position the shadow of the great tuberosity stands out most clearly.

The portion of the greater tuberosity detached may be only a thin sliver of bone, or it may be the whole tuberosity. Following fracture of the greater tuberosity there will be considerable limitation of motion at the shoulder, especially external rotation and abduction will be lost. Internal rotation will be very much increased because of the unrestricted action of the subscapularis, whose attachment to the humeral shaft remains intact. External rotation is lost because of the detachment of the supra- and infra-

spinatus and the teres minor. There will be tenderness in the region of the tuberosity. Later there will be atrophy of the supra- and infraspinati muscles due to their retraction and lack of use.

If reduction of this small displaced fragment is not completed, there may be formed an excessive amount of callus, limiting movements of outward rotation and limiting also abduction and elevation of the scapula outward. These latter limitations will be due to the impinging of the callus on the acromion or glenoid.

The *treatment* will depend upon the displacement of the fragment. If the fragment is not much displaced the upper arm may be put in the position of slight abduction or simply retained by swathe around arm and body and the forearm supported by a cravat sling. After two or three weeks active motion may be begun. Massage to the shoulder should be employed from the time of the injury. The maintaining the abducted position to hold the fragments together may be assisted by the suspended Thomas arm splint (see Figs. 279A, 290, 326). The position of extreme abduction and external rotation of the humerus

Fig. 356.—Line of incision with flap retracted for exposure of upper end of humerus, showing spine of scapula and posterior border of deltoid (Phemister).

Fig. 357.—Flap thrown forward and outward, exposing broken-off tuberosity (*a*) and its attached muscles; fractured surface of humerus (*b*), and circumflex nerve and vessels to the deltoid (*c*) (Phemister).

will prevent callus forming which will interfere with complete abduction after healing. The collar button and hair-pin accessibility will be possible (Jones). If there is considerable displacement of the fragment very complete abduction and possibly maintaining the arm above the head will secure apposition and union of the fragment. Incision and nailing of the great tuberosity to the shaft may be indicated.

The displacement is often posteriorly. The approach to this fracture is not satisfactory through an anterior incision. The lateral incision is simple and if carefully followed should be ordinarily satisfactory. By this route the fragment of the tuberosity may be reached through a splitting of the fibers of the deltoid. If the extension downward of the incision is not carried too far the innervation of the deltoid will not be exposed. The nerve supply enters the deltoid from behind at about the middle of the muscle. A splitting of the deltoid is sometimes followed by atrophy of the muscle-fibers anterior

to the splitting. A good incision probably is that devised by Kocher from the tip of the acromion along the whole spine of the scapula and then at an acute angle along the whole posterior border of the deltoid, as seen in Figs. 356 and 357.

The *x*-ray will assist in distinguishing between a simple fracture of the greater tuberosity, a bursitis, a fracture of the acromial process or rupture of the supraspinatous tendon—all of which must be considered in this connection.

Fracture of the lesser tuberosity of the humerus is unusual. It is ordinarily discovered by the roentgenogram. Stereoscopic plates should be taken if it is suspected. Treatment will be by internal rotation and adduction with the forearm flexed at a right angle. If it appears that the subscapularis

Fig. 358.—Roentgenogram of a fracture through the base of the greater tuberosity of the humerus. Note prominence of tuberosity in its changed position (Holmes).

Fig. 359.—Roentgenogram of fracture and displacement of the greater tuberosity of the humerus (Holmes).

is completely detached and greatly separated, operative treatment should be considered. The operative approach to the lesser tuberosity fracture should be carefully chosen.

Treatment.—For purposes of treatment fractures of the upper end of the humerus may be grouped into two large groups: first, those with little or no displacement, with a simple interlacing of cancellous irregularities on the fracture surfaces, slightly impacted cases, and second, those fractures with displacement.

First Group. Fractures Without Displacement.—Certain anatomical neck fractures, certain few surgical neck fractures, and certain replaced or simply started epiphyseal line fractures will fall into this first group.

Fig. 360.—Fissure of shaft of humerus near anatomical neck and running down into shaft (Beck).

Fig. 361.—Fissure of high shaft of humerus. Compare Fig. 360 (Beck).

Fig. 362.—Fracture of the surgical neck of the humerus.

Fig. 363.—Same as Fig. 365 after replacement of the fracture by incision and direct leverage.

These will not require active treatment, but careful restraint of the upper extremity for a comparatively short time. It may be that only a cravat

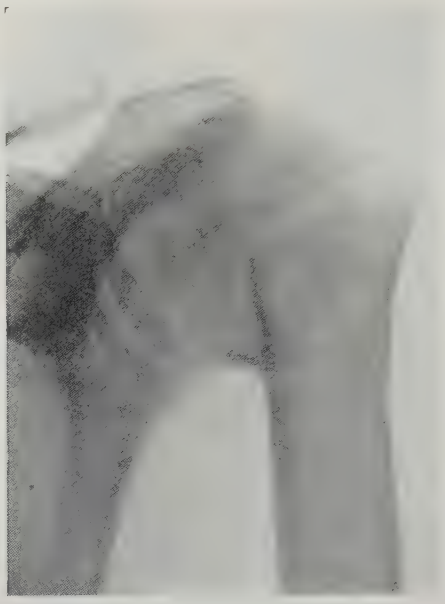


Fig. 364.—Fracture of the surgical neck of the humerus. Traction, abduction, and rotation might alone correct this displacement. Incision, leverage, rotation, and digital confirmation will surely correct this type of fracture. Some of these fractures come for treatment many days after the injury, then incision is always indicated.

Fig. 365.—Fracture of the surgical neck of the humerus with considerable shortening of the arm. Note great displacement upward of lower fragment. Incision, traction, and leverage indicated under these conditions, together with abduction. Palpation of the fractured ends and the securing of dovetailing of the fragments is desirable in order to secure accuracy of replacement.

sling and steadying swathe encircling the injured upper arm and body will be needed for comfort and immobilization.

If greater security and protection are demanded the following is a simple immediate method of treatment for fracture of the anatomical and surgical neck without displacement: The upper arm, shoulder, and trunk should be thoroughly powdered. The hand, forearm, and elbow should be bandaged evenly and smoothly with a bandage of flannel not cut on the bias or a woven A. C. E. bandage. A V-shaped pad (with the apex of the V in the axilla), constructed of sheet wadding with card-board outside and covered with cotton cloth, should be placed in the axilla of the injured side (Fig. 366). This pad is firm, and fitted to the trunk in order to support the inner side of the upper arm (Fig. 367). If thought wise, a thin coaptation splint may be placed between this pad and the inner side of the upper arm for more direct

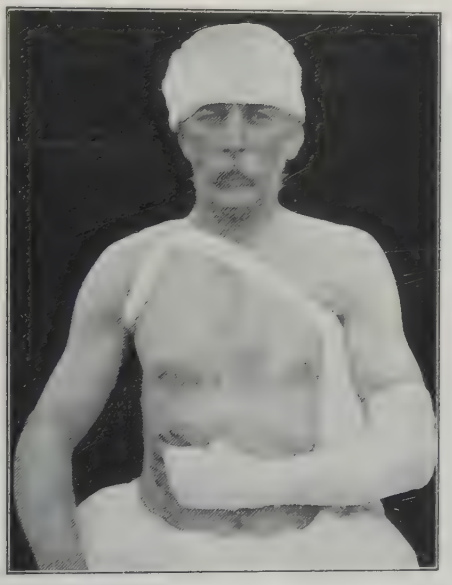


Fig. 366.—Fracture of the upper end of the humerus. Note hand, forearm, and elbow bandaged evenly and without compression; axillary pad and strap.

support. The forearm is held flexed. The shoulder is now well padded with one layer of sheet wadding.

A thin plaster-of-Paris shoulder-cap is applied so as to cover accurately the whole shoulder, the anterior and posterior aspects of the chest, and the outer side of the upper arm down to the external condyle of the humerus (Fig. 368). The shoulder-cap may be frequently omitted. It affords comfort and protection, at times desirable and much appreciated on the part of the sensitive patient. The use of the shoulder-cap is desirable only during the period of acute sensitiveness.

This shoulder-cap is made of washed crinoline, six layers thick, into which has been rubbed plaster-of-Paris cream. Its exact shape and extent are seen in the plates. This shoulder-cap of plaster-crinoline may be dispensed with safely if the patient is absolutely amenable to control.

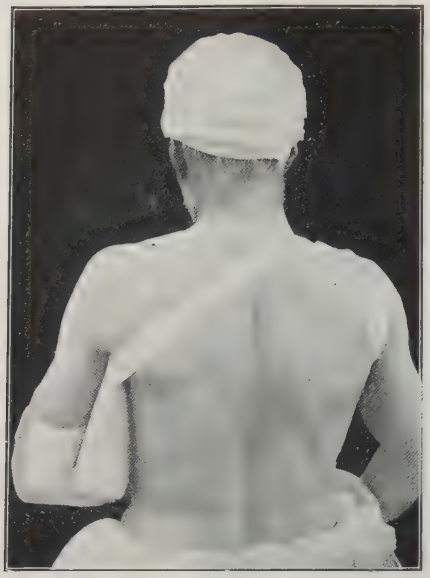


Fig. 367.—Fracture of the upper end or shaft of the humerus. Posterior view. Note bandage to forearm and elbow; axillary pad and strap. Note shape of axillary pad.

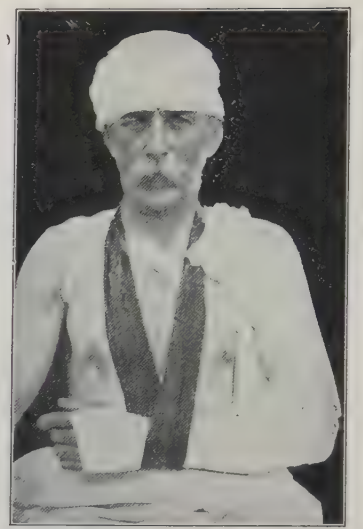


Fig. 368.—Fracture at upper end of the humerus. Note hand, forearm, and elbow bandaged; axillary pad and strap, plaster-of-Paris shoulder-cap, sling.

Fig. 369.—Fracture at upper end of humerus. Arm and elbow bandaged. Axillary pad and shoulder-cap in position. Application of circular bandage to trunk and shoulder. Sling not shown.

Fig. 370.—Plaster-of-Paris splint applied in the abducted position of the arm with the arm rotated inward to maintain the reduction of a separation of the upper humeral epiphysis (Albee).

A gauze bandage, encircling the trunk, arms, and shoulders, should be used in order to hold the upper arm at the side, and closely applied to the co-

aptation splint and the axillary pad, and in order to secure the shoulder-pad firmly in place. Often better than the plain gauze bandage is a roller bandage of unwashed crinoline, which is applied just after dipping it in lukewarm water (Fig. 369). The starch of the crinoline bandage, after

Fig. 371.—Cleary modification of aëroplane splint showing adjustments and positions. (From Magnuson and Coulter, in International Clinics, vol. iv, Series 30, J. B. Lippincott Co., Publishers.)

being wet, stiffens the crinoline as it dries and makes a particularly firm and efficient dressing. A towel folded thin or a piece of compress cloth should be placed against the trunk upon the well side. Against this the circular turns of the bandage rest, thus causing less discomfort to the pa-

tient than if they bear directly upon the chest. The forearm is supported by a cravat sling (see Fig. 368). By this method of immobilization no active traction is exerted upon the lower fragment. The weight of the arm, being unsupported at the elbow, exerts slight traction upon the humeral fragment.

On account of the absence of active traction ambulatory apparatus cannot hold a fracture of the shoulder properly if there is much displacement, particularly if the fracture is oblique. Ambulatory apparatus can modify muscular action, insure quiet and rest to the part, and, except in the instances just noted, approximately maintain the position secured by manipulation and traction and countertraction. On account of its limitations, therefore, it is important that this apparatus should be removed at regular and frequent intervals and that the whole shoulder should be examined by *x*-ray in order to determine errors in position and, if possible, to correct them. Reapplication of the apparatus will afford greater comfort.

After-care of a Fracture of the Shoulder.—Ordinarily the great swelling associated with this injury disappears in two weeks. As the swelling subsides the normal contour of the shoulder becomes apparent again. It is necessary, therefore, to alter the shoulder splint and to apply a fresh one. When the patient wearing a shoulder-cap lies down there is a tendency for the shoulder-cap to ride up and away from the shoulder. This can be guarded against by carrying the retaining bandage under the firm axillary pad and well over the shoulder. Pressure points should be carefully watched for, and any undue pressure removed. In the course of the treatment of a single case this change of dressing will have to be made two or three times. Union will be firm in from three to four weeks. As soon as union is firm all retentive bandages may be omitted. The forearm should then be held by a sling supporting the wrist. At night it will be wise to apply a single swathe the first week after the apparatus is left off in order to avoid undue motion at the shoulder during sleep.

In these injuries about the shoulder-joint active guided motion should be permitted rather early. At the end of two weeks or two weeks and a half repair will have proceeded far enough to allow of the gentlest movement at the shoulder without causing any displacement of fragments. The sooner these gentle movements can be resumed at regular and short intervals, the more rapidly the shoulder will improve. The common occurrence of a periarthritis after an injury to the shoulder emphasizes the necessity for massage. It should be begun as early as the first week.

Second Group. Fractures with Displacement—Fracture of the Surgical Neck of the Humerus.—Considering the displacements of the bone fragments, the damage to the shoulder-joint capsule, to the muscles and muscle attachments accompanying every displaced fracture of this region, considering these anatomic conditions, it is evident that the best position in which to place the upper extremity is in wide abduction and external rotation.

In order to overcome the shortening of the upper arm the abducted position alone is insufficient. Shortening can be overcome most easily by adequate traction and countertraction.

The disability, which is very serious following these injuries to the upper end of the humerus, is a limitation of abduction and of rotation outward. Coupled with these two limitations of movement there is almost always considerable loss of power in the shoulder.

Because these fractures are potential sources of serious disability treatment should aim at an anatomical restoration of fragments with good functional results in as short a time as possible (Blake, Worcester, Sever, Santee).

Method of Reduction.—A general anesthetic is essential. The use of the fluoroscope is also essential; lacking this, Roentgen plates for record should be used.

With the patient lying on the back under complete anesthesia, all muscles relaxed, with provision for countertraction by a folded sheet passed about the thorax high in the axilla, traction should be made on the lower fragment gradually carrying the extremity into complete abduction.

Manipulation and pressure over the lower fragment when it is quite clear of the upper fragment will bring the fragments into apposition.

Rotation, sometimes ever so slight, of the lower fragment (inward or outward according to the degree of displacement), with the forearm at a right angle with the arm, will often secure apposition of fragments.

When reduction is completed the upper extremity should be held in the abducted and externally rotated position.

With the patient in bed this can very conveniently be accomplished by means of a sling to the upper arm, with the forearm flexed and a sling to the forearm (see Figs. 373–375). At times these simple positions assumed are inadequate to hold the fracture reduced. It will then be found necessary to add to the suspension traction (see Fig. 375).

The combination of suspension with traction and abduction and rotation outward is very effective; a combination serving in restraint of displacement, shortening, and subsequent functional disability.

If the mere reposition of a fracture in this region can be secured by the correct position, and traction appears to be unnecessary, then the ambulatory splint may be considered as helpful.

The splints of Cleary, of Sever, or of Leland may be used.

Very careful checking of the position of the upper end of the lower fragment is essential by repeated regular Roentgen-ray examinations. The displacement of the distal fragment occurs unannounced and unattended by discomfort.

I see no good reason for not treating these important cases always as bed cases. Under bed treatment adequate control is most likely from all points of view. Bed treatment will ordinarily be required about two to three weeks. Then the patient may be up with an ambulatory splint, gradually bringing the extremity to the side.

There will be cases of surgical neck fracture which have been unsatisfactorily treated—having characteristic shortening and deformity. These

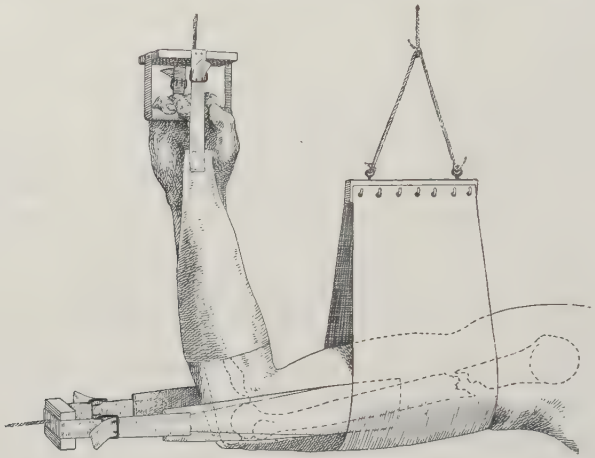


Fig. 372.

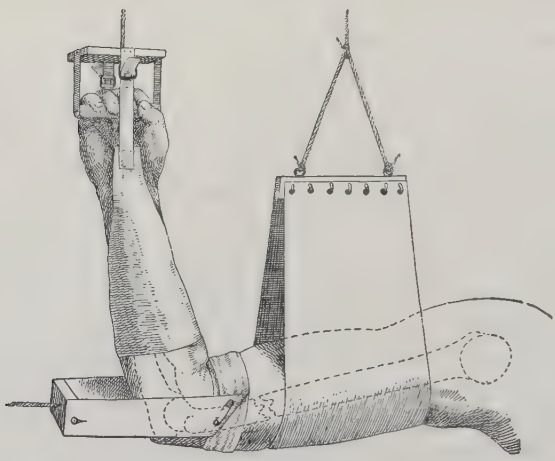


Fig. 373.

Figs. 372, 373.—Detail of method of suspension and traction for fracture of the humerus: Suspension of forearm is made by bands glued to skin and which are attached by straps and buckles to a wooden spreader. A round wooden handle is attached by pieces of elastic webbing to ends of spreader, thus enabling patient to exercise the fingers. The arm is suspended by a sling of rubber sheeting, one end of which is tacked to one side of a wooden spreader; the other end is pierced with eyelets which hook over hooks on the other side of the spreader, so that the sling can be reduced for dressings. Traction in case of high fracture (Fig. 372) is made by bands glued to the skin of the arm and attached by buckles and straps to a wooden spreader. In low fractures (Fig. 373) by doubled band of muslin 6 cm. wide fastened as shown about the padded arm just above the elbow. The padding under the band has been omitted in the drawing for the sake of clearness. In practice with compound fracture the Dakin pad over the wound suffices. Screw heads on the ends of the spreader button into holes in the ends of the band. (Blake.)

cases will at times respond to bed treatment, abduction, and traction gradually increased.

If reposition is impossible in these older cases, operative treatment should be used.

Fig. 374.—Improved abduction board for treatment of fractures of the humerus. The long horizontal member is placed transversely under the mattress. The vertical member is adjustable angularly with the horizontal member by means of the bolt and wing nut connecting them. The pulley for the traction cord is mounted on a cross-piece which can be raised or lowered on the vertical member so as to correspond with the level of the humerus. (See Fig. 375.) (Blake-Bulkley.)

Fig. 375.—Method of installing traction with suspension for fracture of the humerus: In this instance traction is made by bands glued to the arm and buckled to a spreader. The pulley for the traction cord is attached to the abduction board, the amount of abduction being adjusted by slipping the board in or out under the mattress. Note the arrangement for suspension, the hand and forearm being suspended in a plane lateral to that in which the arm is suspended. For details of improved abduction board see Fig. 374. (Blake.)

In those cases in which the lower fragment is displaced inward it is frequently necessary to pull this fragment down before the position of abduction can be reached. The ultimate aim in all cases is to reach a position of abduction and external rotation as soon as possible (Worcester).

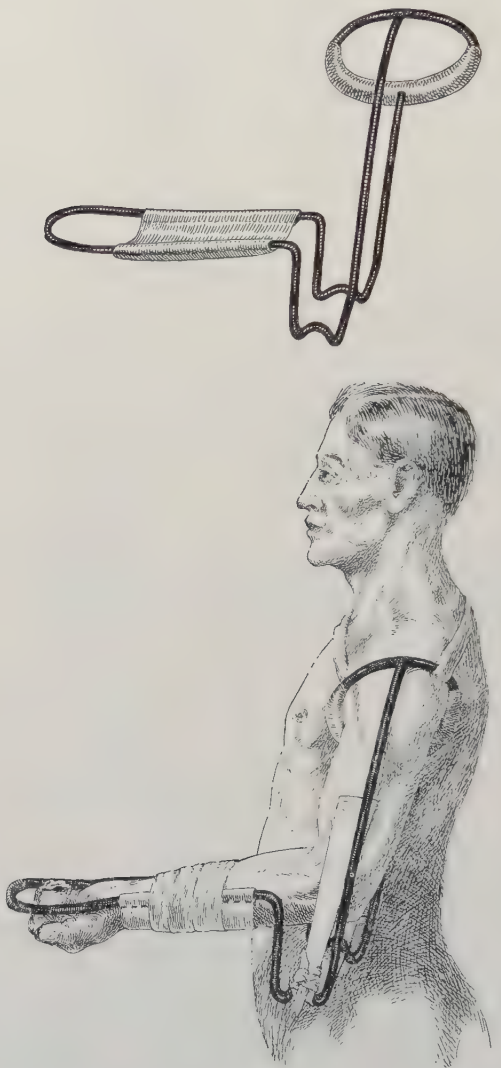


Fig. 376.—The Jones traction humerus splint. The ring encircling the shoulder and the simple uprights are readily understood. This splint is made in rights and lefts, and is applicable to the ambulatory treatment of fractures of the humerus not requiring a position of abduction. It is also useful in some fractures of the forearm. Traction may be made by a hitch about the padded elbow or as shown in this illustration. (Blake.)

It is becoming more and more certain that the universal custom of treating fractures of the upper extremity in an ambulatory fashion is not satis-

The accompanying illustrations (Figs. 372, 373, 375, 377) demonstrate the very simple method of applying the traction bed treatment. I have

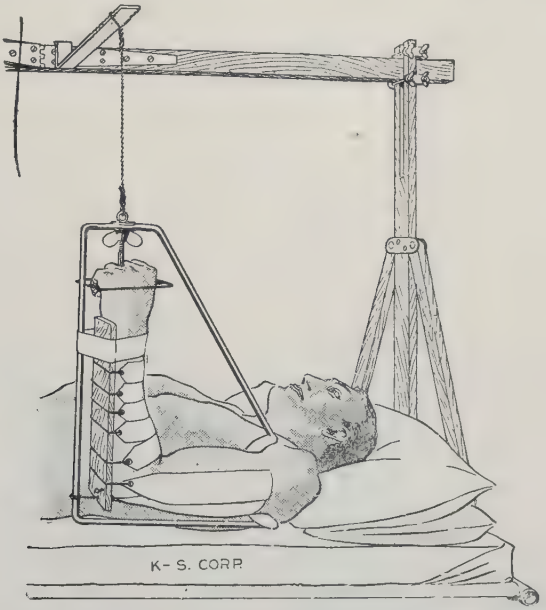


Fig. 377.—The Hawley triangular arm splint for the immobilization of forearm, elbow, or arm with or without traction. Illustration shows splint applied with patient lying in bed and the arm in adduction (Kny-Scheerer).

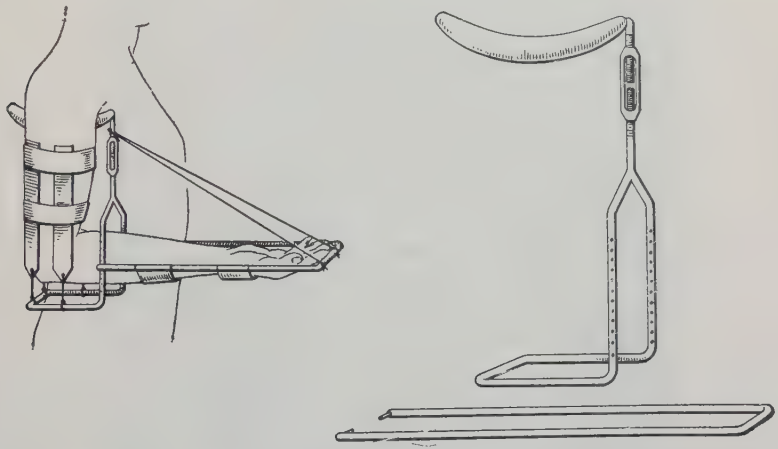


Fig. 378.—Arm splint, after the Pecharmont model. Note excellent exposure for manipulation; x-ray examination; traction by three adhesive straps; use of coaptation splints; traction is regulated by the turnbuckle screw. This splint permits easy motion of elbow and shoulder, including rotation. It may be used as an emergency splint (Hawley, Kny-Scheerer).

made the legends of these illustrations sufficiently full so that no detailed description is needed here.

The necessity for traction or countertraction, abduction, and rest in bed will be determined by the exigencies of the individual case. The Blake ab-

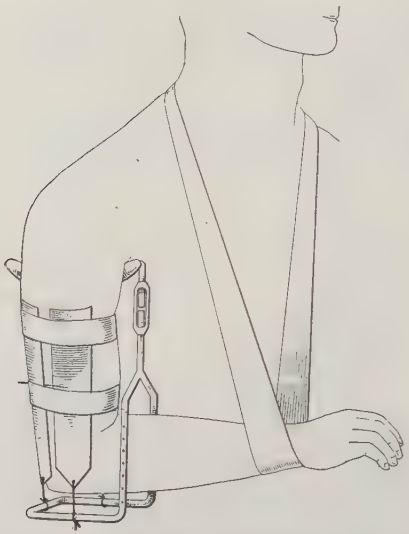


Fig. 379.—Arm splint showing traction by three adhesive straps (Hawley, Kny-Scheerer).

Fig. 380.—Case of a boy fourteen years of age. Comminuted fracture of the surgical neck of the humerus (x-ray taken five weeks after the injury). Notice rotation of the head of the bone, callus, fragment between shaft and epiphysis (C. B. Porter).

duction board (see Figs. 374, 375) or the Thomas arm splint (see Fig. 288) may be used in bed abduction treatment advantageously.

Prognosis and Results.—Following fracture of the upper end of the humerus, including the surgical neck, the early traction and abduction treatment will ordinarily be followed by perfect functional results.

If the initial abduction traction treatment is delayed, if the patient is very old, if the reduction of the fracture is incomplete, the result may be unsatisfactory.

The results of treatment may be measured approximately by a method used by Santee, viz.:

Abduction measured in degrees with digital fixation of the inferior angle of the scapula.

External rotation in abducted position with the forearm flexed—good if 20 degrees or more beyond the sagittal plane.

Fig. 381.—After operation. Silver wire seen *in situ* (C. B. Porter). Same case as that of Fig. 380.

Internal rotation in abducted position with forearm flexed—good if 45 degrees or more below the horizontal. By this notation good external rotation reaches to the back of the head and good internal rotation reaches to the sacro-iliac region of the same side, *i. e.*, good "collar-button function" and good "apron string function."

Joint motion following fracture may be lost entirely or restricted for three reasons: by some mechanical obstruction due to a displaced fragment, by cicatricial contraction in tendons or soft parts or by distorted joint surfaces. Consequently, it is important not only to approximate an anatomical reposition of fragments, but to institute early guided active movements.

The Prognosis in Separations of the Epiphysis.—Bony union is to be expected. If there is little or no displacement of fragments, complete restoration of function will result. If there is some deformity remaining after consolidation of the injury, the usefulness of the shoulder is ultimately and usually restored. The deformity becomes less apparent as the sharp bony corners are smoothed off by the newly forming callus. It is not to be forgotten in considering the prognosis after all shoulder injuries that much of the persisting disability may result from too prolonged immobilization of the arm, even though bony displacement may not have been very great. The growth of the shaft of the humerus in length proceeds largely from the upper epiphysis. It has been thought by many that an arrest of growth of the humerus will follow separation of this upper epiphysis. A loss of growth is not likely to occur in mere separation, but may follow extensive injury to the upper humeral epiphysis.

Oblique Fracture of the Surgical Neck with Great Displacement.—This fracture can sometimes be held by placing the patient in bed upon the back and making direct traction to the upper arm and countertraction upon the shoulder by weight and pulley (see Figs. 372, 373, 375, 377). If the fracture cannot be easily held reduced, it will be wise to make the closed fracture open and to unite the two fragments by suture (see Figs. 352, 354).

The Operative Treatment of Fractures of the Upper End of the Humerus.—So great may be the disability from unreduced fractures of this region in active adults that if non-operative reduction cannot be secured operative replacement is to be undertaken.

FRACTURE OF UPPER END OF SHAFT, WITH DISLOCATION OF THE HUMERAL HEAD

Fracture of the Surgical or Anatomical Neck of the Humerus, or Separation of the Upper Epiphysis of the Humerus, Together with a Dislocation of the Upper Fragment.—The head of the humerus is found in an unnatural position and it fails to move when the arm is rotated. This is generally thought to be an unusual accident, but by careful examination many of these cases may be detected. During the attempt at reduction of a dislocated shoulder fracture of the humeral shaft is liable to occur. Among many cases of fracture of the surgical neck the fracture had occurred fifty-nine times while an attempt at reduction of a dislocation of the shoulder was being made.

Treatment.—Obviously, attempts at reduction by manipulation in the usual way will meet with failure. An attempt should always be made to reduce the dislocation by abduction and traction upon the upper arm and pressure with the hand upon the loose head in the axilla. It may be possible to reduce the dislocation in this manner. If this method fails, an attempt should be made to reduce the dislocated head by open incision (arthrotomy) and manipulation of the upper fragment assisted by the McBurney-C. B. Porter hook maneuver. If this attempt is successful, the shaft should be sutured with an absorbable suture or fine aluminum bronze wire or held by some non-absorbable fixation to the reduced head, and the shoulder treated as if a closed fracture existed.

If it is impossible to reduce the dislocated head, or if the head is much comminuted, it will be necessary to excise it.

If operative interference has been decided upon, it is best to defer the operation until the acute symptoms have subsided and the damaged tissues have recovered themselves. It is the result of experience that operation through acutely damaged tissues is unwise. The vitality of the tissues is lessened by trauma, hence the resistance to infection is temporarily impaired.

If the reduced head of the humerus becomes necrosed and abscesses form about the joint, an unusual occurrence, the head of the bone should be immediately excised (see Unreduced Dislocation of the Humerus).

Fig. 382.—*x*-Ray showing fracture of the greater tuberosity with dislocation of the head of the humerus.

The After-treatment of Operated Cases.—If reduction and suturing have been accomplished, active motion should not be allowed until the reparative process at the seat of fracture is well under way. This will be about the second week. Then gentle movement may be permitted and gradually increased.

If resection has been performed, active and passive motion should be gently begun almost immediately—*i. e.*, within the first forty-eight hours—and persistently continued. The muscles of the shoulder should be massaged and treated by electricity. Abduction should not be attempted to any great extent for some weeks after the operation for fear of displacing the upper end of the humerus. The final results following reduction and suturing have been, as a rule, excellent, useful arms resulting in most cases. The results following excision are only fairly satisfactory. If the proper amount of bone has been removed, ankylosis will not occur. If too much bone has been removed, a dangling or flail joint will result. An excision is to be avoided if possible.

Indications for and Results of Excision of the Shoulder-joint for Fracture and Dislocation.—Excision of the shoulder may be indicated for: (1) ankylosis caused by tuberculosis, by an infectious arthritis, or by a fracture; (2) for a crush of the upper end of the humerus, *i. e.*, comminuted fracture; (3) for an irreducible dislocation of the humeral head; (4) for a disloca-

tion of the humeral head associated with a fracture of the anatomical neck, surgical neck, or greater tuberosity.

By an excision of the shoulder in this connection is understood ordinarily not the removal of the articular upper end of the humerus and the glenoid surface of the scapula, but the removal of the upper end of the humerus solely. The so-called "excision," therefore, is a partial excision, not a complete excision of the shoulder-joint.

The amount of bone removed will, of course, depend upon the exact lesion present. The smaller the amount of bone removed, the better. If there is an anatomical neck fracture with a dislocation, usually it is wise to remove the anatomical head of the bone. If there is a surgical neck fracture every effort should be made to reduce the displaced head, and then to secure apposition of the fractured bones. The removal of the head and shaft above a surgical neck fracture may be at times absolutely necessary, but it may result in great impairment of motion at the shoulder-joint. Reattach tendinous insertions.

I have studied the results of excision of the shoulder in 19 cases. All were subcoracoid dislocations of the shoulder excepting 2; one of these was a posterior dislocation and one was a subglenoid dislocation. These cases, coming from one clinic, that of the Massachusetts General Hospital, have been treated under very similar conditions. They are comparable cases. They form a group of very considerable practical importance.

The mortality in these 19 cases is zero. The results obtained in this group, together with those found in the carefully analyzed series of cases in literature, consisting of 21 excisions (Mason[1]), establishes a standard for excisions of this joint in 40 comparatively recent cases.

Following the excision of the upper end of the humerus there will be limited power in the shoulder; a distinct diminution in strength; limited active motion in abduction, in adduction, and in anterior and posterior swing; muscular atrophy; possibly the formation of plaques of new bone about the old joint from detached periosteum. These pieces of new bone may seriously impair motion. Deformity and pain may follow an excision of the shoulder-joint.

These 19 operations were done either immediately after the receipt of the injury or in from one to eight months following the injury. Twelve of these excisions of the shoulder were for fracture or dislocation, the remainder were for tuberculosis. Almost always the anterior incision was employed. Many of the results were functionally useful. The surgeon's standard of result is high. The patient's standard of result is relatively low. The surgeon is looking for restoration to the normal, an absolute result. The patient is looking for an amelioration of the disability occasioned by the original accident—any improvement is, therefore, hailed by him with delight.

It is very generally accepted that the reposition of the head of the dislocated humerus is the ideal treatment for cases of fracture dislocation or of unreduced dislocations, because the reports from such reposition give better functional results than treatment by any other method.

[1] Annals of Surgery, May, 1908.

The result following an operative reposition or reduction is better always than the result of an excision. For this reason Curtis has very properly designated (and Mason has lately followed Curtis) the results of reposition as *perfect*, *good*, and *fair;* while the results of excision of the shoulder are classified as *good*, *fair*, *improved*, and *bad*. The best excision can only be a *good* result. It is never equal to the *perfect* reposition. The *fair* or second-best excision will be no better than a *good* reposition. This classification of results has been used in studying the cases here recorded.

In certain cases an arthroplasty of some form may improve the results of simple reposition even beyond what they are at present. The better

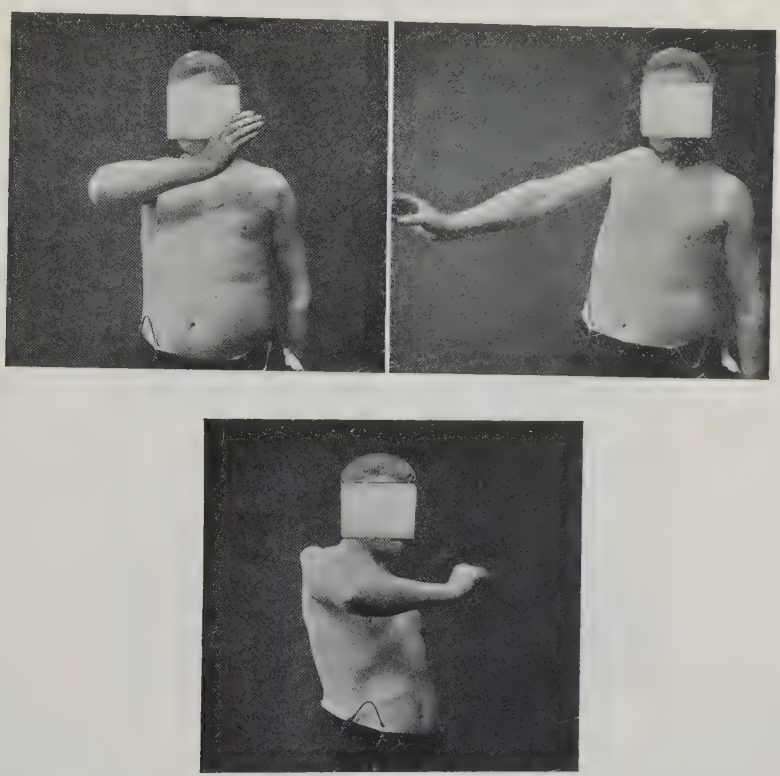


Fig. 383.—Fracture dislocation of the right shoulder. Excision. Condition eight years subsequently (M G. H. series).

functional result of operative reposition over excision should induce the surgeon to make every effort at reposition before excising the head of the bone. Berg assembled fragments about a graft driven into the shaft.

I am quite positive that excision is too often done because it is a little easier and quicker than attempts at operative reduction. If one wishes to secure ultimately the best for his patient, he will make safe but strenuous efforts to reduce the head of the bone and not to excise it. The too frequently poor result following excision emphasizes the importance of this suggestion as to treatment.

An individual unable to put hand to head, unable readily to feed himself because of limited power in forward swing and abduction—incapacitated for the ordinary acts of life, to say nothing of loss in trade or business —is seriously handicapped. Functionally, the result of a dislocated shoulder replaced by manipulation may be serious; of a fracture dislocation of the shoulder replaced by incision may be much more serious; of a fracture dislocation excised may be most serious.

About 59 per cent. of these cases had fair results. I am impressed by the disability following excision of the shoulder.

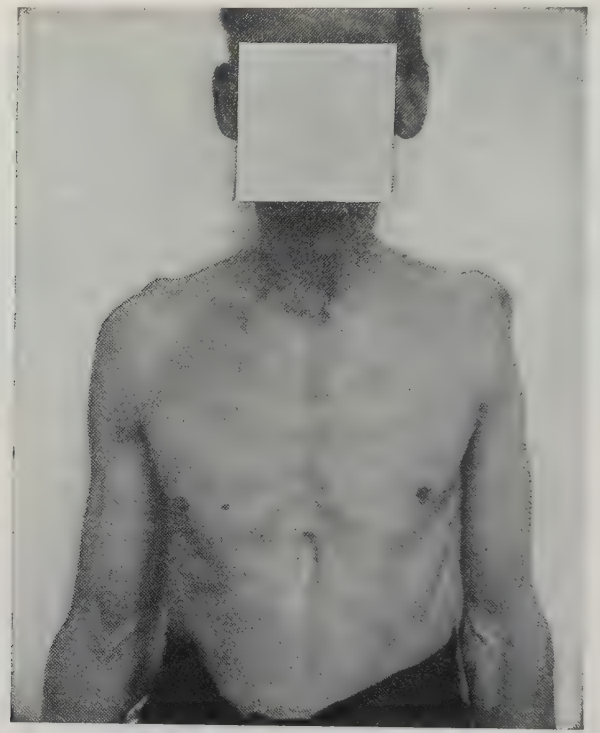


Fig. 384.—Fracture dislocation of the left shoulder. Excision of the head of the humerus. Result nine years later. Note the atrophy of the deltoid on the left side. Works every day. Note the deformity of the shoulder region (M. G. H. series).

The farther away from the joint the fracture occurs—*i. e.*, the nearer the fracture is to the shaft—the greater is the likelihood of being able to reduce the displaced head by hook, by digital pressure, by periosteum elevator, or by blunt dissector leverage. Every reasonable effort should be made to secure an ideal result. Reposition is ideal. Excision at best is but second best.

There are very few cases on record in which the surgeon has fixed the fracture of the shaft by a carefully applied steel plate held by screws and then has reduced the displaced head assisted by the artificially immoblized fracture.

Case of Fracture Dislocation of the Right Shoulder. Excision of Humeral Head.—Report eight years after operation (Fig. 383).

S. F. H., No. 104,073. Dentist. A man sixty-four years old. Eight

weeks before he had received, through a fall, a fracture of the humerus and a dislocation of the head of the bone. Excision of the head of the humerus was done. The wound was drained.

Eight years subsequently the following report is received. He is able to do a great deal of work with the arm. He can put the index-finger to the lobe of the ear. He cannot feed himself with that hand. He has little trouble excepting some rheumatism at times (Fig. 383).

Case of Fracture Dislocation of the Left Shoulder. Excision of the Head of the Humerus.—Result nine years later (Fig. 384).

A. F. P., No. 105,896. A man forty-eight years old, a sailor. Following a violent blow upon the left shoulder two months ago a fracture of the anatomical neck together with a dislocation resulted. All motions of the shoulder were much limited and painful. An excision of the head of the bone was done with difficulty. The chisel was needed to free the bone completely. Many periarticular adhesions were divided. Nine years later he reports that he is able to work every day. The arm bothers him very little. He cannot put his right hand upon his head, but he can put on and take off his hat with his right hand. He says his arm is as good as he can expect. Ten years later he can place hand on neck, but not on shoulder. He can move in abduction 45 degrees. He can put hand behind back (Fig. 384).

Case of Fracture of the Anatomical Neck of the Right Humerus with Dislocation of the Shoulder. Excision of the Head of the Humerus.—Report after nine months.

G. A. Male clerk, thirty-one years old. Fell and sustained a subcoracoid dislocation of the right humerus six weeks previously. Because of a fracture of the anatomic neck of the humerus it was impossible to reduce the dislocation. Consequently, an excision of the head of the bone was performed through the anterior incision.

Nine months later he has fair use of the arm. All attempts at abduction are associated with movements of the scapula (Figs. 385, 386).

Case of Dislocation Fracture of the Left Shoulder. Irreducible. No Operation Done.—Result six years after the accident (see Fig. 388).

The patient is able to put the left hand upon the top of his head without bending the head more than a trifle. He cannot quite place the left hand squarely upon the right shoulder. He can place the left hand behind his back, but a little less readily than the right hand.

He can raise his left arm to a horizontal in the forward swing. He can abduct the left arm slightly beyond a right angle.

There is a little difference in his reach, the left arm being slightly shorter than the right. The left arm hangs away from the side further than the right. The back of the left hand faces forward.

He has some discomfort at times because of a little "catching," as he expresses it, in the left shoulder. The left arm gets a little more tired at times (Figs. 387, 388).

This case of unreduced and unoperated fracture dislocation of the shoulder is most instructive. The patient was an adult, a superintendent in a brew-

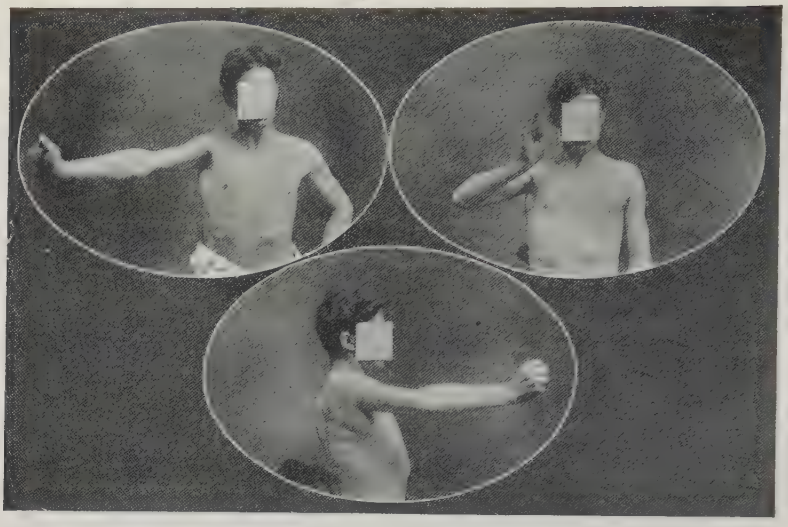


Fig. 385.—Fracture of the anatomical neck of the humerus. Excision of the head of the bone. Result nine months later (see Fig. 386).

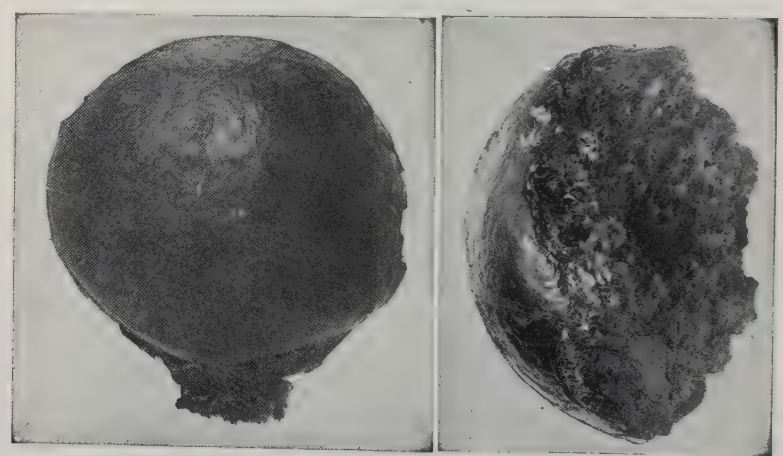


Fig. 386.—Anatomical neck fractured in Fig. 384. This is the head of the bone removed (see Fig. 385).

Fig. 387.—Irreducible fracture dislocation of the left shoulder, unoperated upon. Condition six years after operation (see *x*-ray plate, Fig. 388).

ery. Six years ago he fell, dislocating the left shoulder, fracturing at the time the greater tuberosity of the humerus (see *x*-ray, Fig. 388). Today, six years after the injury, he has recovered, with a remarkably useful shoulder, although the humeral head is still dislocated. The extent of the movements of the shoulder-joint is best seen in the photographs (see Fig. 387). He complains only that the arm becomes a little tired after some hours' walking about. It seems to him less well supported at the shoulder than the

Fig. 388.—*x*-Ray of Fig. 387, showing fracture dislocation of the numeral head. Note greater tuberosity fractured. Note loss of contour of end of the bone. Six years since accident.

other arm. Resting the hand in the coat for a few moments relieves him of this tired feeling.

Other similar cases have been recorded. The results in certain unoperated and unreduced dislocations are as good as in some excisions of the shoulder, and are often better than in many excisions of the shoulder.

If reposition by manipulation or incision is impossible, and there is no pain for which excision is demanded, it may be wise in a certain very limited class of cases to avoid an excision of the head of the bone. Certain it

is that in a few irreducible and unreduced cases of dislocation of the upper end of the humerus a remarkably good result has followed without excision.

FRACTURES OF THE SHAFT OF THE HUMERUS

Little displacement—Axillary pad, coaptation splints, sling—Osgood splint—v. Hacker splint—Spica—Much displacement—Jones extension splint—Hawley extension splint—Bed traction and suspension—Active motion—Prognosis—Conditions governing selection of splints for any fracture.

Fracture of the shaft of the humerus may occur at any point between the surgical neck and the condyles. Fracture is caused by direct or in-

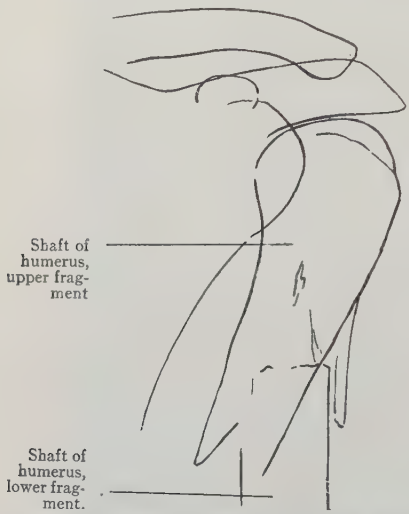


Fig. 389.—Fracture of shaft of humerus, high. Displacement of lower end of upper fragment inward (*x*-ray tracing).

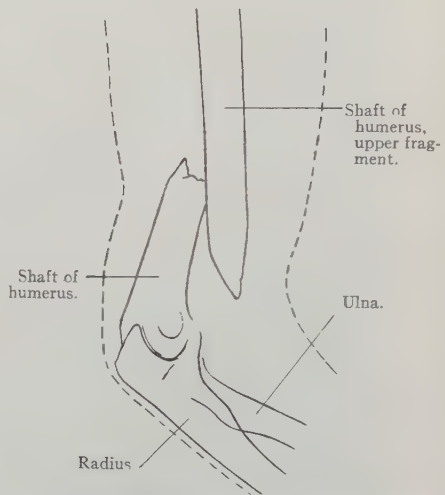


Fig. 390.—Fracture of the shaft of the humerus in lower third. Displacement of both fragments forward (*x*-ray tracing).

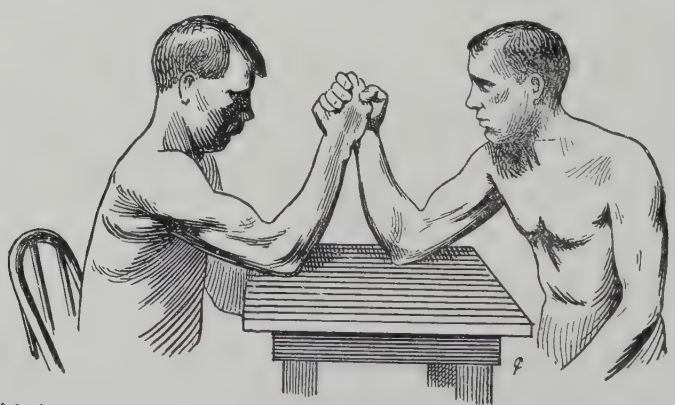


Fig. 391.—Trial of strength of arms resulting sometimes in spiral fracture of the humerus (Monks). (See Fig. 392.)

direct violence. Torsion of the bone and muscular action, as in throwing a baseball, may be causes of fracture of the shaft. Its common seat is at the

Fig. 392.—Illustrating spiral fracture of humerus (Monks). (See Fig. 391.)

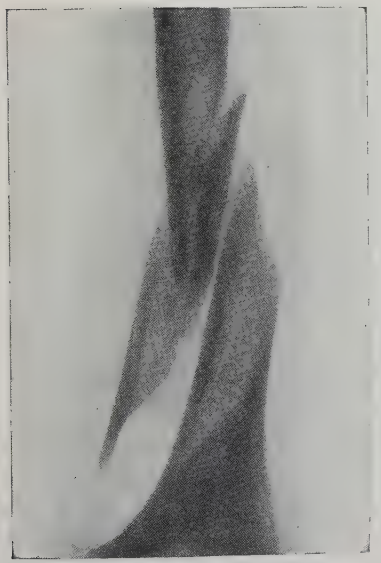


Fig. 393.—Anteroposterior view. Same case as Fig. 394. Comminuted fracture of shaft of humerus. Note the displacement of fragments and obliquity of lines of fracture. The application of a steel band would reduce the fracture, but it is not necessary to use a steel band.

Fig. 394.—Lateral view of comminuted fracture of the shaft of the humerus. Note spiral and oblique lines of fracture. Displacement and shortening. There was no nerve involvement. Same case as Fig. 393.

middle or in the lower third of the bone (Fig. 390). The twisting force exercised in the breaking up of adhesions in and about the shoulder-joint

will often fracture a humeral shaft obliquely. The strength test of the arms, as seen in the illustration, has been the cause of spiral fracture of the humerus (Figs. 391, 392).

Symptoms.—The symptoms are readily recognized. They are swelling at the seat of fracture, pain, crepitus, abnormal motion, and ecchymoses. Paralysis of the musculospiral nerve may occur, with the characteristic wrist-drop. Ordinarily, the attention of both the patient and the surgeon is so occupied with the fracture of the bone and its associated loss of movement that loss of power and sensation, because of involvement of the nerve,

Fig. 395.—Same case as Figs. 393, 394. Treated by *immediate* traction and coaptation splints. Illustrating the effect of utilizing by traction the coapting and lateral pressure of the muscles and fascia.

goes unrecognized. If injury to the musculospiral nerve is not recognized at the outset, it may be overlooked until the splints are removed. The exact duration and the cause of the paralysis cannot then be readily ascertained. The patient may wrongly attribute the paralysis to the pressure of the splints. Very rarely injury or pressure upon the large vessels of the arm is met with. Damage to the artery will be suggested by weak or absent pulse at the wrist or by local evidences of hemorrhage. A swelling appearing suddenly, greater than that which would appear from the laceration of soft tissues alone, should suggest rupture of large vessels. Measurement of the humerus should be made from the edge of the acromial process to the external

Fig. 396.—Longitudinal fracture of shaft of humerus into the joint. Displacement of smaller fragment backward. Note space between fragment and shaft. Arm extended.

Fig. 397.—Method of application of Jones' humerus traction splint: Traction may be obtained as indicated by means of a strap passing over the upper end of the forearm, in which case a thick felt pad should be interposed between it and the skin. In other cases traction is obtained by adhesive strips applied to the mesial and lateral skin surfaces of the upper arm. (See Figs. 376, 378.) (M. G. H. Conference.)

Fig. 398.—Fracture of the shaft of the left humerus. Note the Jones traction splint applied; method of securing traction by windlass and countertraction in axilla against side of body (Leland).

Fig. 399.—Same case as seen in Fig. 398. Posterior view of Jones' arm splint. Note windlass for extension; fitting of leather padded ring to the axilla (Leland).

Fig. 400.—Fracture of the left humerus at the junction of lower and middle thirds of the shaft. Compound fracture of both bones of the left leg. Injury to the head of the fibula of the right leg, with temporary injury to the right peroneal nerve. Note suspension of both lower extremities; suspension and traction of upper arm (Leland).

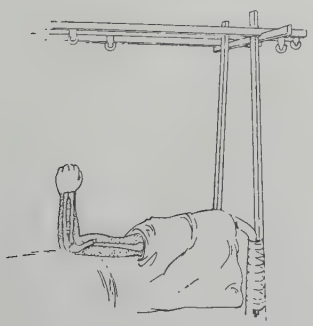


Fig. 401.—Schematic outline drawing. Fracture of humerus in lower third as admitted to the hospital. Note the displacement of fragments. Patient lying in bed; arm supported with elbow bent to a right angle (M. K. Smith).

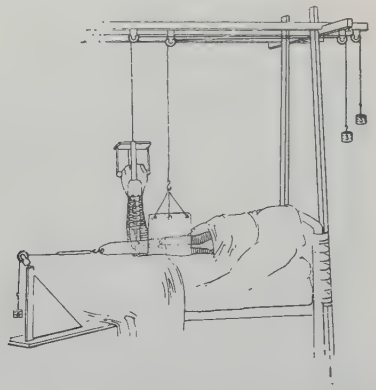


Fig. 402.—The arm is suspended. The position of the fragments is improved, but there is insufficient traction and too heavy weight on the arm. Note uncorrected position of fragments. Note board under mattress holding pulley on upright (M. K. Smith).

condyle of the humerus (see Fig. 333). The amount of overlapping of the fragments will be shown by this measurement.

Treatment.—For purposes of treatment, fractures of the shaft may be grouped into those with little or no displacement and those with considerable displacement and difficult of retention after reduction. The fracture should be reduced by traction upon the condyles of the humerus and countertraction upon the upper arm and by manipulation of the fractured bones.

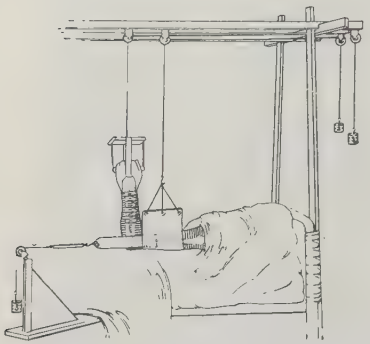


Fig. 403.—The traction has been increased and the weight on the arm diminished. The alignment is now good (M. K. Smith).

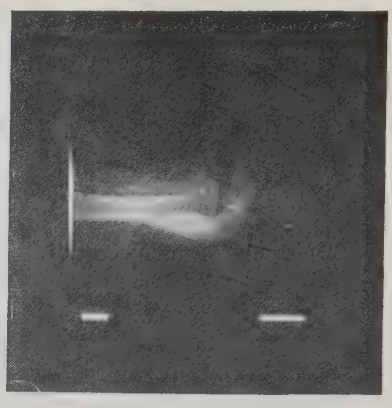


Fig. 404.—Compound fracture of the lower third of the humerus, insufficient weight. *x*-Ray; patient lying in bed (M. K. Smith).

A. *Treatment of Fractures of the Shaft of the Humerus with Little or No Displacement* (Figs. 410, 411).—The treatment here described is satisfactory for many fractures of this special type —*with little or no displacement.* The following materials are needed for the apparatus to be used: Ordinary dusting-powder (which is powdered oxid of zinc and powdered starch, equal

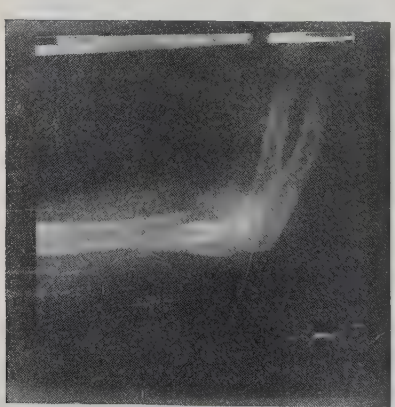


Fig. 405.—Same case as Fig. 404. *x*-Ray; suspension weights adjusted; note improvement in position of fragments (M. K. Smith).

Fig. 406.—Comminuted fracture of humerus. *x*-Ray (M. K. Smith).

parts); a bandage of Shaker flannel 3 inches wide, not cut on the bias or a woven bandage A. C. E.; an axillary pad made with several layers of sheet

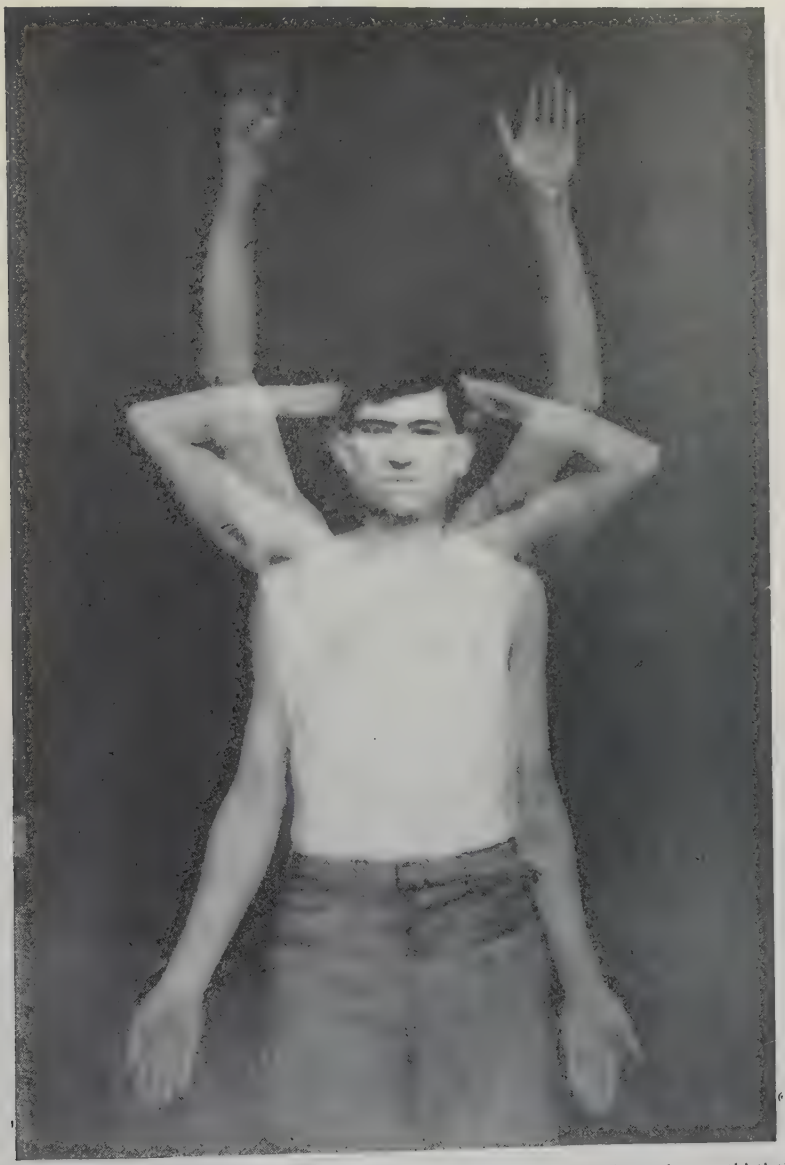


Fig. 407.—Fracture of humerus, comminuted (same as Fig. 406). Beginning union on thirtieth day. Consolidation on the forty-fifth day. Sequestrotomy on the forty-sixth day. Note method of superimposed photograph for recording results—accurate and telling (M. K. Smith).

wadding covered with a folded piece of pasteboard, and the whole inclosed in cotton cloth stitched at the edges; the pad is V shaped, and long enough to extend from the apex of the axilla to just above the internal condyle of

the humerus; it is broad enough to support the upper arm comfortably and securely; the lower part of the pad is about 3 inches thick (Fig. 412), so as to support the arm only a trifle abducted from the side—that is, just away from the perpendicular. If the axillary pad is too short there is danger of causing an outward bowing of the humerus (see Fig. 422). Two straps are attached to the upper corners of the apex of the V-shaped pad long enough to surround the body and go over the opposite shoulder. These straps hold

Fig. 408.—Compound fracture of humerus suspended in abduction. Note suspending and traction method. Note receptacle (x) containing solution for irrigation of wound (M. K. Smith).

the pad in position. The remaining apparatus consists of two or three thin coaptation splints for application to the upper arm; these are made readily by laying thin splint wood upon adhesive plaster, and splitting the wood longitudinally (Fig. 413); three adhesive straps 2 inches wide to hold the coaptation splints; an adhesive plaster swathe wide enough to extend from the

Fig. 409.—Same as Fig. 396. Note the disappearance of space between fragments with correction of deformity upon flexing forearm. Position reduces the fracture.

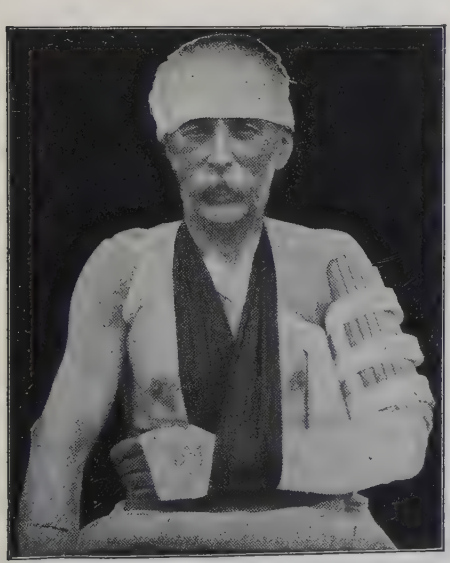


Fig. 410.—Fracture of the shaft of the humerus. Note bandage to hand, forearm, and elbow; axillary pad and strap; coaptation splints and sling. Bandage does not cover fracture.

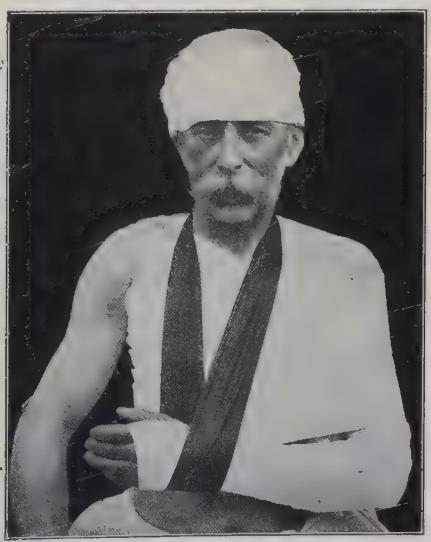


Fig. 411.—Fracture of the shaft of the humerus. Note bandage to hand, forearm, and elbow; adhesive plaster swathe holding arm upon axillary pad and covering coaptation splints. Sling.

acromion tip to the external condyle, and long enough to surround the body and upper arm; a cravat sling; a thin towel or piece of compress cloth for the forearm to rest upon. All these articles should be in readiness.

Etherization of the patient will rarely be necessary. In cases of nervous and sensitive women and unmanageable young children it will be wise

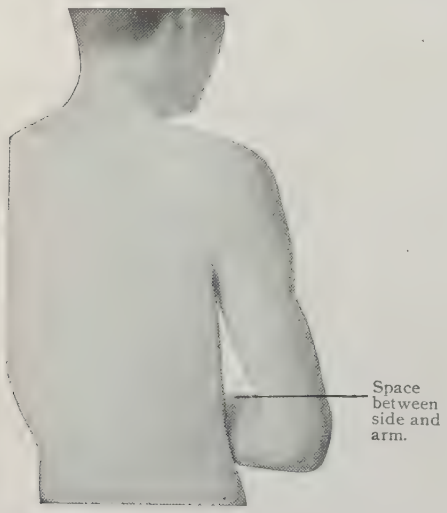


Fig. 412.—Note the space to be filled by suitable pad between the inner side of upper arm just above elbow and the chest and loin in case of fracture to shaft of humerus.

Fig. 413.—Coaptation splint seen flat and in section. Made by laying thin wood on adhesive plaster and splitting the wood with knife.

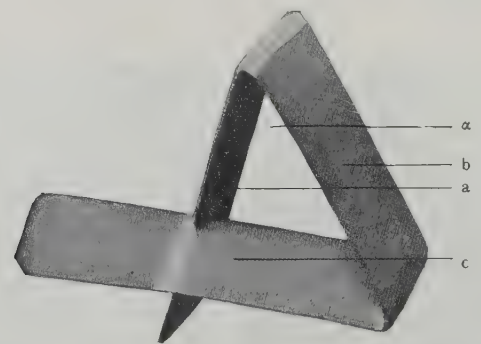


Fig. 414.—A splint for holding comfortably and advantageously a fracture of the shaft of the humerus. Splint made of heavy cardboard reinforced by adhesive plaster strips. (v. Hacker's Clinic.)

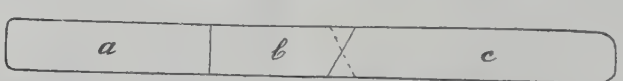


Fig. 415.—The strip of heavy carboard or mill board, showing in diagram proportional length of the three parts *a*, *b*, *c*, and the oblique bending of the strip. (v. Hacker's Clinic.)

to use an anesthetic. The whole upper extremity, axilla, and chest should be washed with soap and water, thoroughly dried, and dusted with powder; then the reduced fracture is held in position by an assistant while the apparatus is being applied. The hand, forearm, and elbow should be loosely

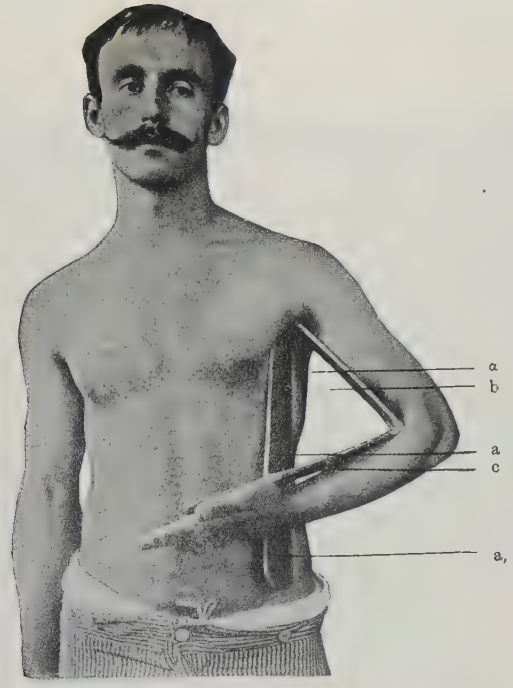


Fig. 416.—Humerus splint in position. (v. Hacker's Clinic.)

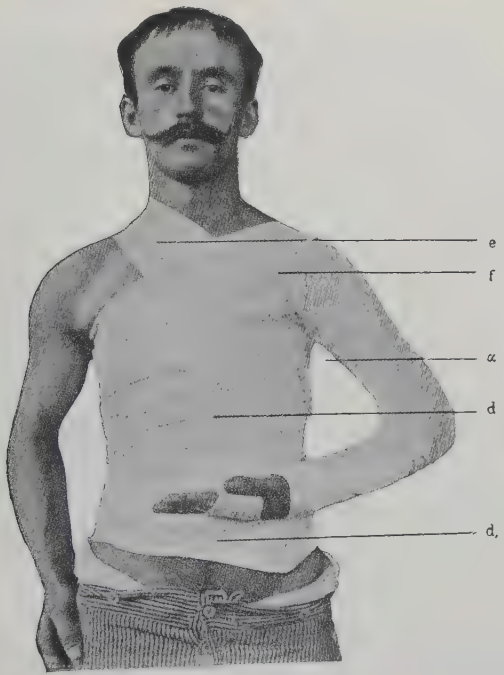


Fig. 417.—Humerus splint in position and held by bandages about neck, trunk, upper and forearm, and hand. (v. Hacker's Clinic.)

but evenly covered by a flannel bandage (see Fig. 366). The upper arm should be surrounded by the coaptation splints, held in place by the three straps of adhesive plaster, so as to secure the fractured bone perfectly (see

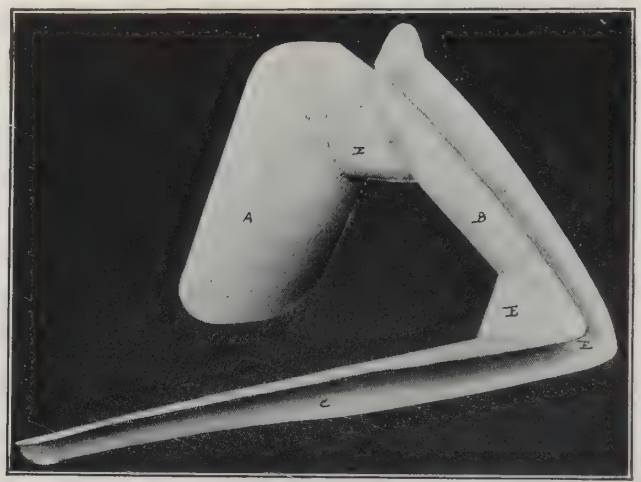


Fig. 418.—Splint for fracture of the humerus: *A*, Chest piece; *B*, upper arm support; *C*, forearm splint; *E*, reinforced angle. (Osgood and Penhallow.)

Fig 410). The axillary pad should be placed in the axilla and held by the straps passed over the opposite shoulder and under the opposite axilla. The upper arm should rest comfortably upon the pad. To prevent cha-

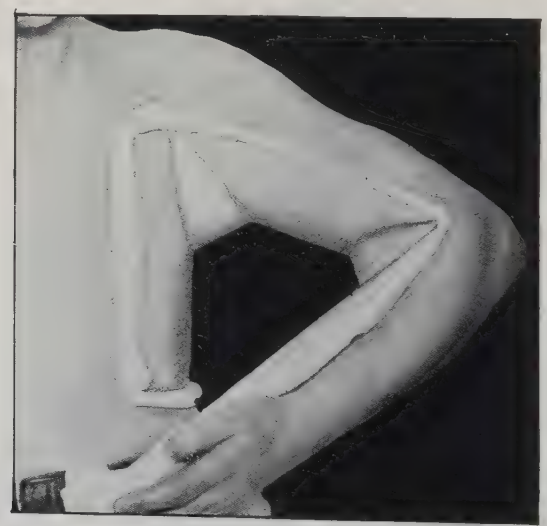


Fig. 419.—Splint for fracture of the shaft of the humerus: Pads applied before adhesive swathe is in place (Osgood and Penhallow).

fing, the thin towel or compress cloth should be placed beneath the forearm where it touches the body. The plaster swathe should then be applied over the arm to the body, so as to encircle completely the trunk (see

Fig. 411). Thus the arm is absolutely fixed to the axillary pad and side. The wrist should be supported in a cravat sling passed around the neck. The elbow is left unsupported. The weight of the upper extremity will thus tend to exert slight downward traction upon the lower fragment of the humerus. Under no circumstances should an ordinary broad sling be used because of the danger of making upward pressure upon the forearm and elbow and so pushing up the lower fragment of the humerus. The elbow-joint should not be immobilized for the reason that it would then be much more difficult to hold the seat of fracture fixed. With the elbow-joint fixed the lower arm of the lever is greatly increased, and instead of

Fig. 420.—Splint for fracture of the shaft of the humerus. Posterior view (Osgood and Penhallow).

movement of the forearm taking place at the elbow-joint it would take place at the seat of fracture (see Fig. 423). Fractures of the shaft of the humerus are frequently treated by an internal angular splint and coaptation splints, the upper ends of the splints barely reaching the fracture, or, at best, being 1 or 2 inches above it (see Fig. 423). When the fracture of the bone is within the lower third of the shaft, then and then only should an internal angular splint be used in connection with coaptation splints. The Osgood and Penhallow splint of tin is sometimes of great service (see Figs. 418–420). The splint of cardboard from the clinic of v. Hacker is often indicated (see Figs. 414, 415).

These latter splints enable the surgeon to control slight deformity at the seat of fracture; the lower humeral fragment, by abduction, will be more nearly brought into line with the upper fragment.

If there is a compound fracture of the humerus, or if the fracture requires considerable permanent traction in order to secure its reduction and immobilization, or if an adjustment involving rotation of the fragments in the long bony axis is required, the method of suspension and traction employed during the war and illustrated by Blake and Bulkley in Figs. 372, 373, 375 will be needed. The Thomas arm splint is at times useful. (See also Figs. 401–408, inclusive.)

Fig. 421.—Ambulatory traction. Fracture of the shaft of the humerus at X. Overriding and lateral displacement of fragments. Note: Coaptation splints, internal right-angle splints. Two weights, one pulling through medium of right-angle splint and the other through adhesive plaster attached to upper arm as high as the seat of the fracture. Note: Sling as a cravat supporting only the wrist. Traction is thus exerted upon the lower fragment of the humerus.

If it is desirable to apply traction and countertraction of moderate degree and allow the patient to walk

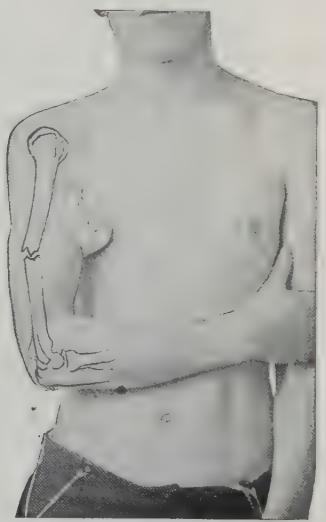


Fig. 422.—Showing effect (bowing outward) of too short an axillary pad upon a fracture of the shaft of the humerus.

about, the use of Jones' splint, seen in Figs. 376, 398, 399, is indicated. Hawley's splint (see Fig. 377) is a comfortable and effective form of apparatus for these cases.

After-treatment.—The patient should be seen each day for the first three days in order that the surgeon may be informed as to the exact condition of the parts. There may be undue pressure. The patient may be uncomfortable. The splints may need readjusting. Attention to little details of discomfort is important. The dressing should be reapplied with great care once each week. The parts covered by splints should at each dressing be carefully inspected to detect any points of undue pressure, indicated by

reddening of the skin. If these are discovered, they should be washed with alcohol and covered with flexible collodion or a drying powder. The undue pressure should be removed by shifting the padding. Union will be found to be firm after about three or four weeks. As soon as union is solid—at the end of four or five weeks—the swathe may be omitted, the coaptation splints alone being a sufficient support. After about five weeks or five weeks and a half all support may be removed from the arm. The arm is then put in the sleeve of the clothes and the wrist supported by a sling. After eight weeks the sling may be discarded and moderate and careful use of the limb in light movements be permitted.

B. *Fracture of the Shaft of the Humerus with Considerable Displacement.*—Obviously, the method described for the treatment of fractures without great displacement will be of comparatively little value. Occasionally it will be found that this method will hold even greatly displaced fractures, it should then be used. The ideally perfect method for such cases is *traction and countertraction* upon the arm with the patient lying on the back in bed (see Fig. 408). Coaptation splints should be used, as in simple uncomplicated fractures. If all methods fail to hold the fragments reduced, open incision, reduction of the displacement, and suturing of the fragments are indicated.

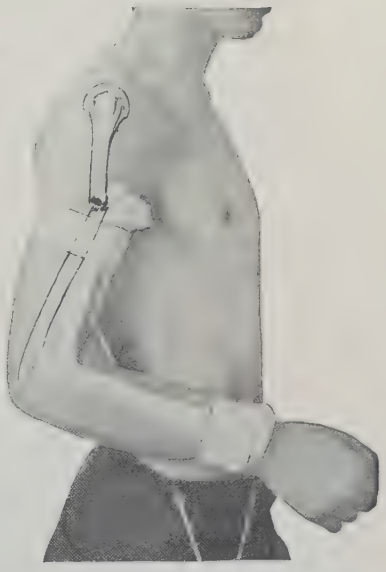


Fig. 423.—High fracture of the shaft of the humerus. A common and improper use of an internal right-angle splint.

The *plaster-of-Paris splint*, applied with the plaster roller to the forearm and arm, and the spica bandage to the shoulder and chest are often efficient in these difficult cases. This method must be very carefully supervised. It should only be used to hold fragments that are pretty accurately apposed. The chief object of this splint is to eliminate the effect of gravity in keeping fragments separated when the patient assumes the erect position. The fragment being replaced and forced into firm apposition, the plaster-of-Paris splint maintains this apposition and at the same time permits ambulatory treatment to be employed. The Roentgen ray must be used as a record of progress. In the application of this splint it is of supreme importance that an assistant hold the arm so that the alignment of the bones remains perfect and by suitable pressure toward the shoulder the contact of fragments is maintained. The assistant who holds the arms should have nothing else to do. Before applying the plaster-of-Paris splint it is often advisable to apply thin coaptation splints at the seat of fracture to give additional strength to the splint. With these coaptation splints in use a lighter plaster splint may

be applied without sacrificing strength. A narrow cotton swathe about the body and arm should steady the upper extremity. The wrist should be supported by a cravat sling.

The after-care of a case treated by the plaster splint will be similar to that following any other treatment after union has occurred. The plaster

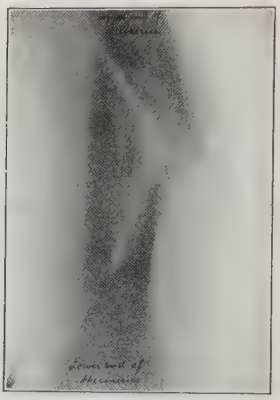


Fig. 424.—Fracture of the shaft of the humerus. Note the loose fragment. Note the comparative ease of complete reduction and retention if fragments are held by encircling suture.

Fig. 425.—Fracture of the lower part of the shaft of the humerus. Note displacement of upper fragment backward.

may be left *in situ* for four weeks; a renewal of the plaster splint after two weeks may be wise; ordinarily after four weeks repair will be found so far advanced that the plaster splint may be dispensed with and the or-

Fig. 426.—Fracture of the shaft of the humerus through condyles. Note displacement of upper fragment backward.

Fig. 427.—Injury to the upper end of the ulna and the lower end of the humerus.

dinary coaptation splints and swathe may be used. If the plaster splint has proved comfortable, it may be split and reapplied.

Massage, Active and Passive Motion.—In view of the possibility of non-union of this fracture, it will be wise not to begin massage until union has begun.

Guarded active motion of the shoulder and elbow should be gently supervised at as early a date as possible, with due consideration to the condition of repair in the fracture. If at the end of three weeks union is found to have begun, it will be wise to move the shoulder and elbow gently by active motion. The seat of fracture should be cautiously guarded against movement during these gentle motions. Protected active movement repeated occasionally during the process of repair will assist very considerably in the restoration of the functional usefulness of the shoulder and elbow, which so often become stiff from immobilization.

Prognosis.—Ordinarily union occurs readily in from four to six weeks. In childhood union is quite solid in from three to five weeks. Fractures of

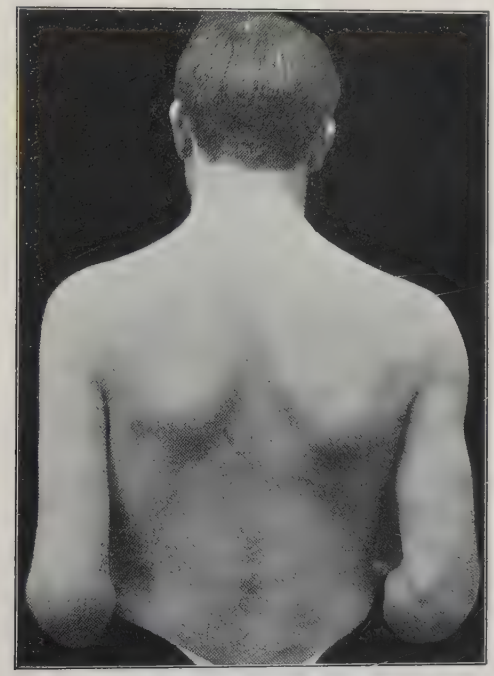


Fig. 428.—Fracture of the shaft of the left humerus. Fracture united. Note atrophy of upper arm, including deltoid. The loss of muscular contour is very apparent.

this bone are more likely to be followed by non-union than fracture of any other bone in the body. For this reason everything possible must be done to prevent delay or non-union. That is, no chance of lack of apposition should be taken. If there is doubt about union occurring, operative reposition should be employed at an early date.

The presence of abnormal mobility after the usual time for bony union to occur (four or five weeks), together with an absence of Roentgen-ray evidence of callus, are evidences of a delayed union. Considerable muscular atrophy follows this fracture (Fig. 428). Upon using the arm again and by massage the size of the arm is, in a great measure, restored. The stiffness of

the shoulder and elbow which is sometimes associated with this injury is due to long immobilization without active or passive motion.

THE SELECTION OF APPARATUS OR SPLINTS FOR A FRACTURE

There are certain conditions which must be taken into consideration before a suitable choice can be made of the splint or splints which are to be employed in a given fracture of bone. These conditions are briefly enumerated:

1. Abrasion of the skin of the part (leg, thigh, arm).
2. Compound wounds.
3. Crush of the soft parts other than the skin.
4. Fractures of adjacent bones.
5. Multiple fractures.
6. Fractures entering joints.
7. Associated injuries to parts of the body remote from the special fracture under consideration.

It is only necessary to call attention here to the fact that if any one or if any combination of these conditions exists then very great judgment is needed in the selection of the form of treatment, whether non-operative or operative, and what particular type of splint is to be used.

CHAPTER XII

FRACTURES OF THE ELBOW

Method of examination—Measurements—Order of examination of elbow after injury—Symptoms of lesions about the elbow—Treatment of fractures about the lower end of the humerus—Method of using the hyperflexed position—Precautions in using the acute flexed position—The after-care of injuries of the elbow—Remarks on elbow injuries—Myositis ossificans—Volkmann-Leser contracture—Fractures of the lower end of the humerus in adults.

FRACTURES of the lower end of the humerus near to and involving the elbow-joint are frequent in childhood, but much less frequent in adults. A familiarity with the bony landmarks of the elbow is essential to an accurate diagnosis. A knowledge of the roentgenological appearances of the

Fig. 429.—Roentgenogram of elbow in extension: Note the epiphyseal lines: radial head, internal epicondyle, lower epiphyses, including the external condyle (Arial George).

elbow-joint bones at all stages of their development is essential to an accurate diagnosis. The more nearly accurate the diagnosis, the more efficient will be the treatment and the more intelligent the prognosis. Almost every elbow injury, no matter how trivial, should be examined under anesthesia.

Method of Examination.—The normal anatomical relations of the uninjured elbow are to be determined first. The large prominent internal condyle of the humerus, the olecranon process of the ulna, the external condyle, the head of the radius, are each in turn to be grasped by the thumb

and forefinger. If these bony points can be recognized upon the injured elbow, then a fracture ought not to be overlooked.

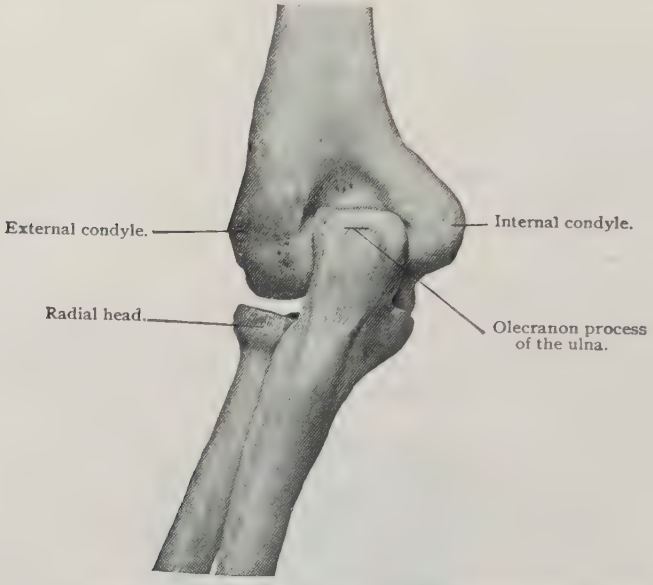


Fig. 430.—Note the bony relations of the internal and external condyles of the humerus and the olecranon process of the ulna in complete extension of the forearm. The three points are almost in a straight line.

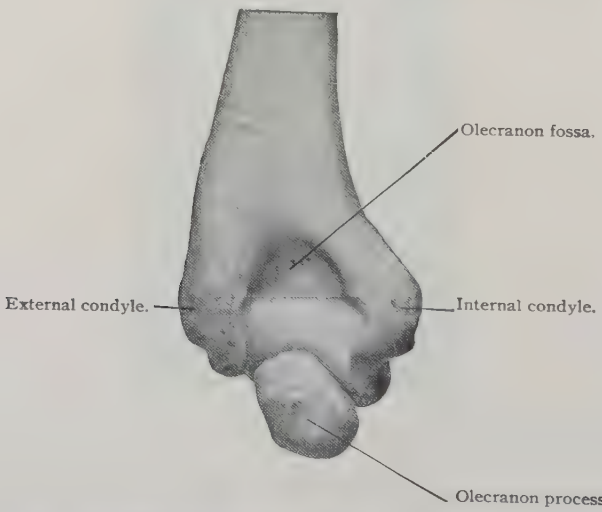


Fig. 431.—Note the bony relations of the internal and external condyles and olecranon process of the ulna when the forearm is flexed to a right angle. The three points make a triangle and lie in a plane parallel with the plane of the posterior surface of the humerus.

The Three Bony Points of the Elbow Region.—With a pencil or ink the internal and external condyles of the humerus and the tip of the olecranon should be marked, the forearm being extended. Normally, these three points will be found to be in nearly a straight line transverse to the long

axis of the limb. The tip of the olecranon is a trifle above this line (Figs. 430–432).

Palpation of the Three Bony Points.—Grasping the left wrist with the left hand, place the right thumb upon the external condyle, the third finger on the internal condyle, and the forefinger on the olecranon. When the elbow is at a right angle, these three points will be found to be approximately in the same plane with the back of the upper arm. A similar examination may be made of the right elbow, changing hands for convenience (see Figs. 430, 433).

The Head of the Radius (see Fig. 436).—Grasping the elbow with one hand, the thumb resting ½ inch below the external condyle upon the head of the radius, and holding the wrist in the other hand, the patient's forearm is pronated and supinated. If the shaft of the radius, including the neck, is unbroken or impacted, the head of the radius will be felt to move under the thumb.

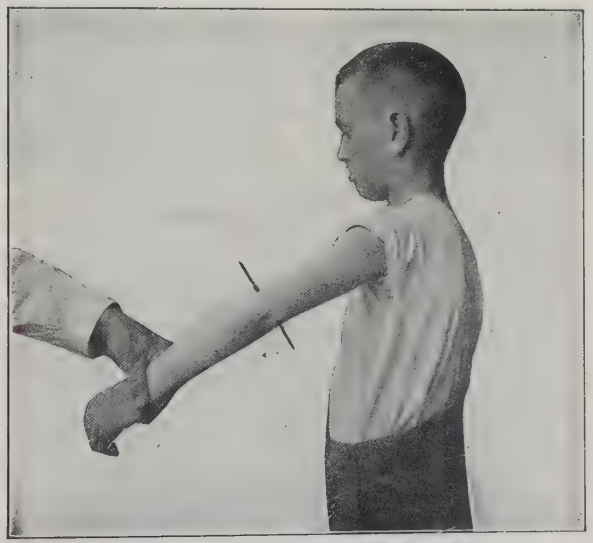


Fig. 432.—Normal elbow. Relation of the three bony points in almost complete extension of forearm. Prominence of olecranon and two condyles evident.

The Carrying Angle (Figs. 434, 435, 443).—The lateral angle that the supinated forearm makes with the upper arm is called the carrying angle. It is important to remember that this angle varies normally within very wide limits. Some individuals have no carrying angle.

The carrying angle is not formed solely by a deviation from the transverse of the lower articular surface of the humerus. There is also a similar deviation in the upper articular surface of the forearm in relation to its longitudinal axis.

Movements at the Elbow-joint.—The movements of the joint should be determined both in flexion and extension. There is normally no lateral motion in the extended elbow-joint. Abnormal lateral motion in either adduction or abduction should be detected if present.

Fig. 433.—Normal elbow. Examination. The three bony points. Note position of the thumb and two fingers of the examining hand.

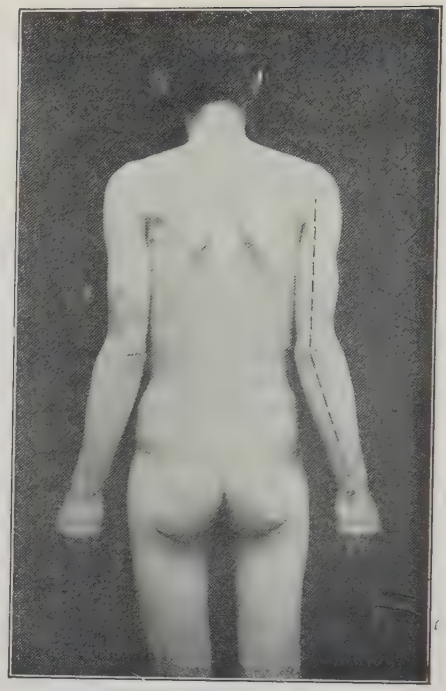


Fig. 434.—Normal elbows. Well-marked carrying angle apparent.

Fig. 435.—Position of supination, showing the carrying angle. The outline shows the position of pronation with disappearance of the carrying angle.

Fig. 436.—Normal elbow. Method of examination. Palpating head of radius. Spot marks external condyle

Fig. 437.—Normal elbow. Method of examination. Grasping the two condyles of the humerus.

Measurements.—The distance between the two condyles should be measured on the uninjured arm. The distance from the acromial process to the external condyle of the humerus should also be measured (see Fig. 333).

Having then established a standard of comparison in the normal elbow, the injured elbow should be examined with the greatest care. Even when there is great swelling of the elbow region, steady pressure will enable the fingers to reach the condyles. In approaching an injury to the elbow the questions which arise are: Is there a dislocation? Is there a fracture? Are both dislocation and fracture present? Is there a contusion and a sprain? Is there a subluxation of the radial head? In the absence of positive signs of dislocation, subluxation, and fracture the lesion is a sprain or contusion. In the absence of positive signs of dislocation and radial subluxation a fracture will be present.

In correcting elbow fractures and replacing the elbow in a position of extreme flexion if the forearm is brought up so that its axis coincides with that of the humerus the carrying angle will be maintained (Ashhurst).

Fig. 438.—Normal elbow. Method of examination. Palpating olecranon.

Summary of the Order of Examination of the Injured Elbow.—Notice whether the swelling and ecchymosis are general or localized. If localized, that may determine the seat of the lesion. Observe the carrying angle. Palpate the external and internal condyles (see Fig. 437), the olecranon process of the ulna (see Fig. 411), and the head of the radius (see Fig. 436). Determine if crepitus is present. See if the head of the radius rotates. Note the relations of the three bony points, with the forearm flexed at a right angle and completely extended (see Figs. 430–433). Note any lateral motion at the elbow-joint (see Fig. 439). Determine the possible movements of the elbow-joint. Make measurements.

Traumatic lesions of the elbow may be grouped, for simplicity and ease of reference, in the following manner. In young children a Roentgen-ray examination may not demonstrate a fracture line because of the fact that calcification of the epiphysis has not occurred. The absence of a positive Roentgen ray under those conditions will not militate against fracture. During the routine examination it is wise to have in mind these possible individual lesions:

Lesions of the Radius and Ulna: (*a*) Dislocation of the radius and ulna backward with or without fracture of the coronoid process of the ulna.

(*b*) Subluxation of the radial head.

(*c*) Fracture of the olecranon process of the ulna.

(*d*) Fracture of the neck or head of the radius.

Lesions of the Lower End of the Humerus: (*e*) Fracture of the internal epicondyle.

Fracture of bones at elbow. Appearances twenty-four hours after the accident. Note great swelling of the whole upper extremity: blebs: abrasions (Mixter, Richardson).

(*f*) Fracture of the internal condyle, including the trochlea and the epitrochlea and entering the joint.

(*g*) Fracture of the external condyle, including the capitellum and epicondyle and entering the joint.

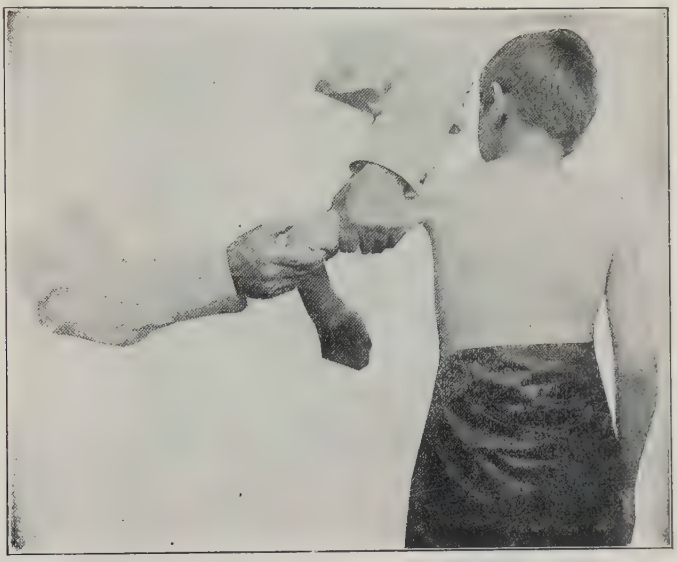


Fig. 439.—Normal elbow. Line between the condyles. Method of examining for supracondylar fracture.

Fig. 440.—Anterior view of lower end of humerus. Note capitellum; trochlear surface; internal condyle.

Fig. 441.—Trochlea, capitellum, epitrochlea, and epicondyle.

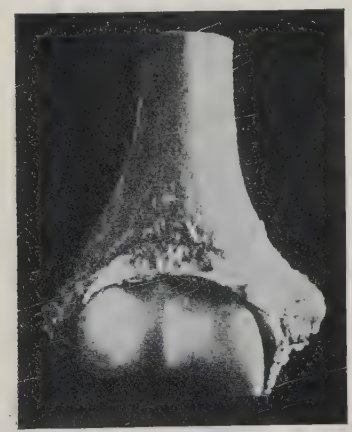


Fig. 442.—Note the attachment of the capsule to the lower end of the anterior surface of the humerus.

(Ashhurst Monograph, Lea & Febiger, Philadelphia and New York, 1910.)

(*h*) Transverse fracture of the shaft of the humerus above the condyles (supracondylar).

(*i*) Separation of the lower epiphysis of the humerus.

(*j*) T-fracture into the elbow-joint.

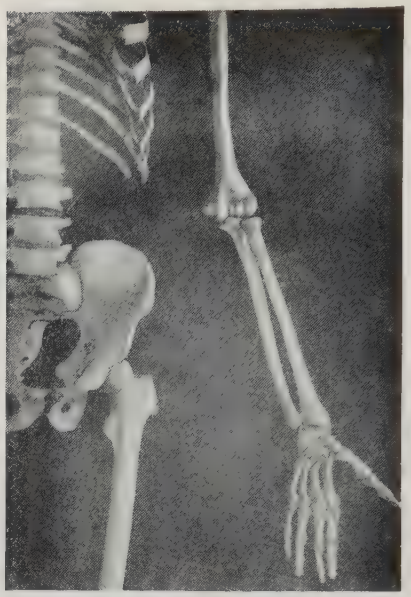


Fig. 443.—Bones of the left elbow-joint, showing the carrying angle (Ashhurst).

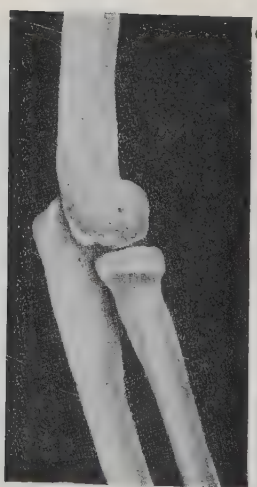


Fig. 444.—Lateral view of lower end of humerus. Note relations of radial head to external condyle (Ashhurst).

Fig. 445.—Lateral view of the flexed elbow. Note relation of radial head to capitellum (Ashhurst).

Symptoms of Lesions About the Elbow-joint with the Differential Diagnosis of Each Lesion.—(*a*) A Dislocation of the Radius and Ulna Backward With or Without Fracture of the Coronoid Process of the Ulna: There

may be very great swelling of the region of the elbow. The relations between the three bony points are disturbed. The olecranon process is very

Fig. 446.—Diagram of fracture of external condyle by abduction of forearm. Lines of force shown by arrows.

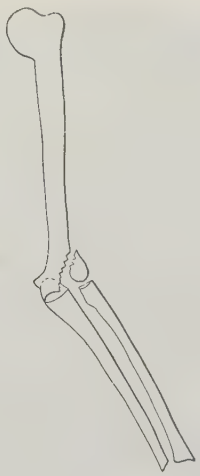


Fig. 447.—Diagram similar to Fig. 446.

prominent posteriorly. The radial head is displaced backward. The two condyles are far in front of the olecranon. There is abnormal lateral mo-

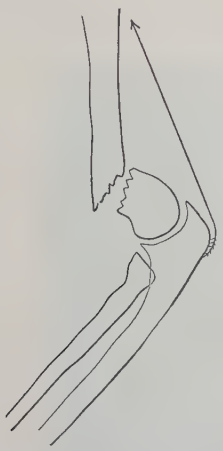


Fig. 448.—Diagram to show the action of the triceps with the elbow in extension.

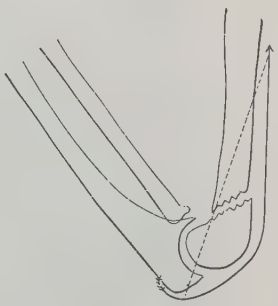
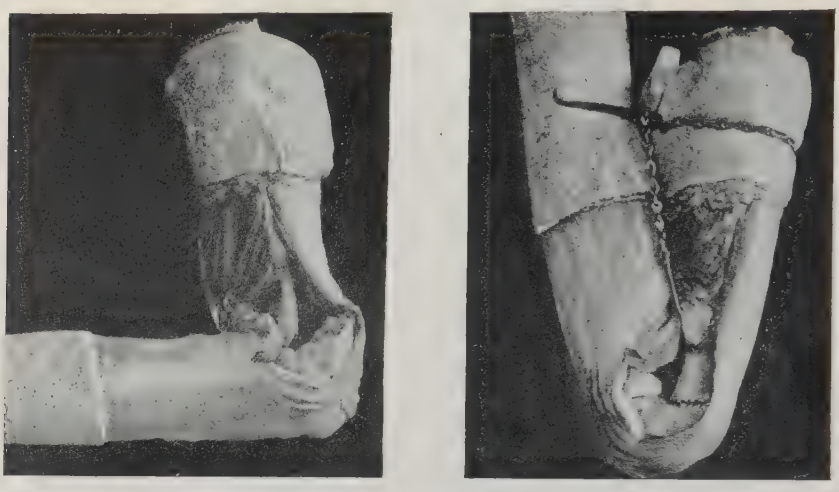


Fig. 449.—Diagram to show the action of the triceps in serving as a splint posteriorly in fracture above the condyles when placed in acute flexion.

(Ashhurst Monograph, Lea & Febiger, Philadelphia and New York, 1910.)

bility. The normal movements of the joint are restricted. This injury may be mistaken for a supracondylar fracture. The important difference has been mentioned. A dislocation of both bones backward, if re-

duced, does not ordinarily tend again to become displaced; if it does, there is most likely a fracture of the coronoid process of the ulna.



a *b*

Fig. 450.—*a*, Dissection of supracondylar fracture of the humerus, showing the displacement of the lower end of the proximal fragment forward into the bend of the elbow. *b*, Note the effect, after replacement of fragments, of the flexed position in maintaining the reduction and in preventing, through position and action of the triceps posteriorly, slumping of the proximal fragment again forward into bend of elbow. Ashhurst.)

(*b*) Subluxation of the Head of the Radius: This takes place in children under five years of age. It is due to sudden traction upon the extended

Fig. 451.—Dissection. Right elbow flexed to show the tension in this position of the posterior branch of the internal lateral ligament. (Ashhurst Monograph, Lea & Febiger, Philadelphia and New York, 1910.)

forearm, which so often occurs in lifting a child by the arm over a curb-stone. The child presents the arm hanging slightly away from the side,

with the elbow a little flexed and the hand semipronated. Attempts to use the arm cause pain. The extremes of flexion and extension and supina-

Fig. 452.—Dissection. Right elbow extended to show the tension on the anterior branch of the internal lateral ligament (Ashhurst).

Fig. 453.—Left elbow extended showing tension on the anterior ligament (Ashhurst).

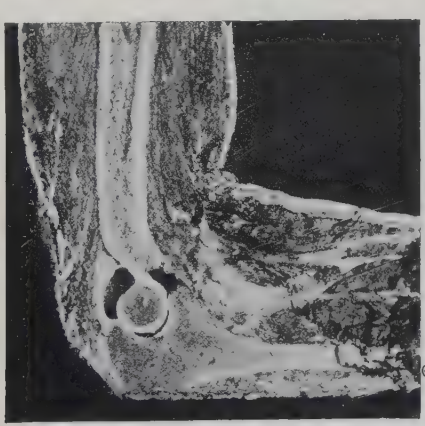


Fig. 454.—Sagittal section of the elbow-joint passing through the coronoid and olecranon fossæ. The capsule was distended before hardening in formalin (Ashhurst).

tion are painful. Inspection will detect a slight swelling $\frac{1}{2}$ to 1 inch below the external condyle of the humerus. Tenderness is present over the head of the radius. The relation of the three bony prominences is preserved.

The details of this not uncommon lesion are mentioned because it is sometimes mistaken for a fracture of the radial head or a simple sprain of the elbow.

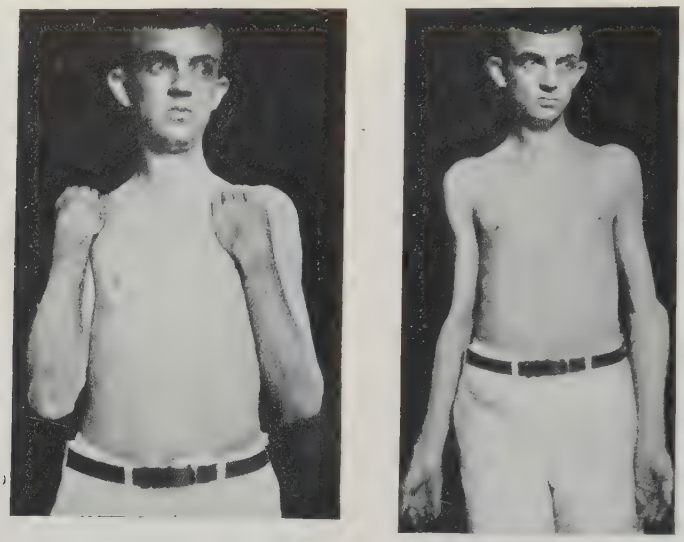


Fig. 455.—A, Note right elbow flexed. Naturally, the forearm lies in line with the upper arm; left elbow flexed, forearm falls on chest and inward to upper arm, deviating from sagittal plane because of fracture. B, Same patient as A. Note right normal carrying angle and left gunstock deformity. This gunstock deformity or cubitus valgus causes the forearm to fall to the inner side of the upper arm (Ashhurst).

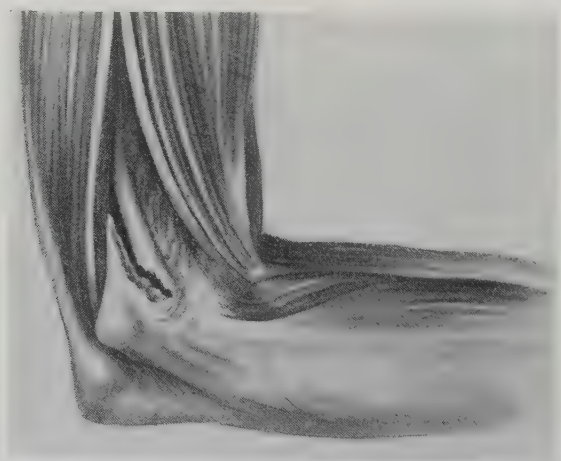


Fig. 456.—Inner view of supracondylar fracture of the humerus. The lower fragment is displaced backward. The upper fragment is displaced forward. Note line of fracture predisposing to this displacement, pull of triceps, ulnar nerve disappearing behind the condyle, brachial artery, median nerve, large vein safely protected by soft tissues from bony fragments (after Davis-Peotti).

A fracture of the radius below the neck has also been mistaken for this subluxation of the head. Careful detailed examination with roentgenograms will alone clear up any doubts.

(*c*) Fracture of the Olecranon Process: The details of this fracture are considered elsewhere. Crepitus and mobility of the olecranon fragment will be felt. There may or may not be separation of the fragments. If there is a separation, it will be detected and the three bony points will have their normal relations disturbed.

Fig. 457.—Lower end of humerus, anterior surface. Note lines of fracture of internal epicondyle and of fracture of external condyle.

Fig. 458.—Lower end of humerus, anterior surface. Note lines of supracondylar fracture and of fracture of internal condyle.

(*d*) Fracture of the Neck or Head of the Radius: This is not uncommon. Swelling over the radial head and neck is present. Supination and pronation are painful and limited and attended by crepitus, muscular spasm, and possibly a loss of rotation of the radial head.

(*e*) Fracture of the Internal Epicondyle: The epiphysis of this epicondyle unites to the shaft of the humerus between the eighteenth and

Fig. 459.—Lower end of humerus, anterior surface. Note lines of T-fracture.

Fig. 460.—Lower end of humerus, posterior surface. Note olecranon fossa and trochlear surface for ulna. Note *projection* of internal condyle.

twentieth years. This fracture is quite common among little children. If this fracture presents a small fragment, it is of little consequence. If a large fragment is broken off, it is of consequence. The displacement is downward and forward. The ulnar nerve is sometimes, though rarely, implicated in this injury.

Fig. 461.—Fracture of the internal condyle. Recovery with "gunstock" deformity, due to slipping upward of fragment and adduction of forearm. Compare with Fig. 455.

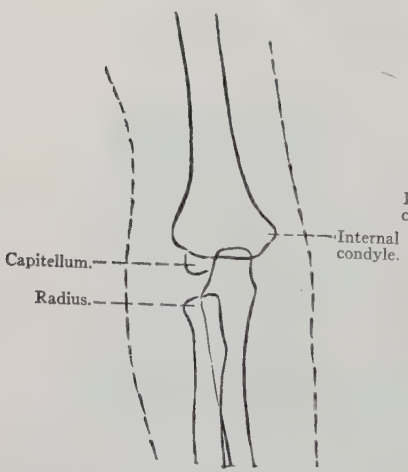


Fig. 462.—Normal right arm of patient in Fig. 461 (*x*-ray tracing).

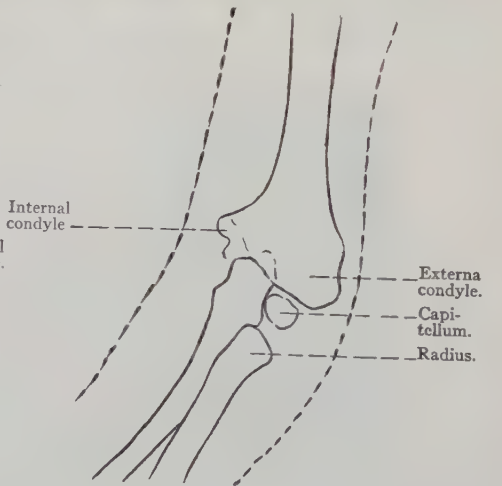


Fig. 463.—Fracture of internal condyle of left humerus. Recovery with deformity. See Fig. 461 (*x*-ray tracing).

(*f*) Fracture of the Internal Condyle: This fracture is, fortunately, not very common. The line of fracture usually enters the joint of the ulnar trochlea. It is a disabling fracture. If there is displacement the humeral

fragment of the condyle will be displaced upward (see Fig. 467). The ulna is the main bone of the forearm, being the anatomical continuation of the humerus, while the radius belongs to the hand (Ashhurst). Interference with

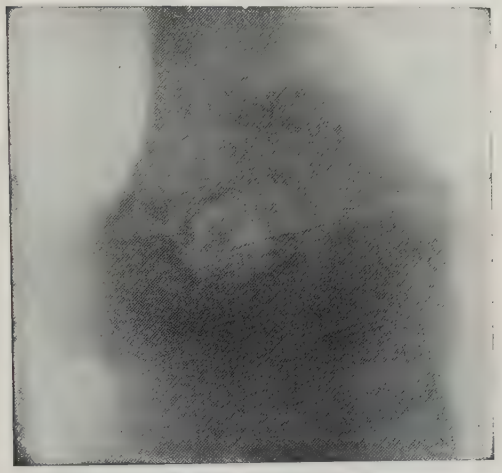


Fig. 464.—Transverse fracture through the lower end of the humerus at level of olecranon fossa. Anteroposterior view. Slight displacement.

Fig. 465.—Same as Fig. 464. Lateral view. Slight displacement.

the humero-ulnar joint may interfere seriously with the movements of the elbow. Swelling over this condyle is marked. By grasping the condyle abnormal mobility and crepitus are detected between the fragment and the shaft.

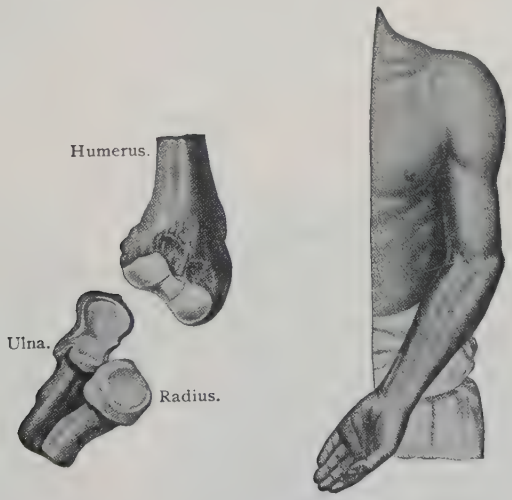


Fig. 466.—Fracture of the internal condyle; displacement upward of fragment; union in displaced position; consequent permanent adduction of forearm. Compare with Fig. 461. (After Helferich.)

The inner of the three bony points is displaced upward. Lateral mobility of the elbow is present; adduction is especially free. The carrying angle will be diminished if there is displacement of the condyle upward (Figs. 461–463).

In the position of hyperflexion the internal condyle cannot move upward nor can it be displaced backward because it is held by the tense triceps (see Fig. 449).

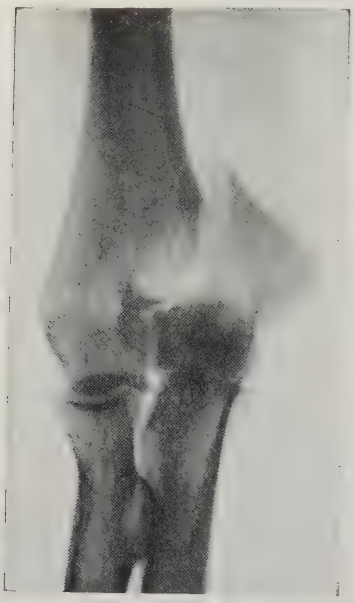


Fig. 467.—Fracture of lower end of humerus through internal condyle (Dodd).

Fig. 468.—Lateral view of Fig. 467. Note displacement anteriorly of fragment in the somewhat extended position (Dodd).

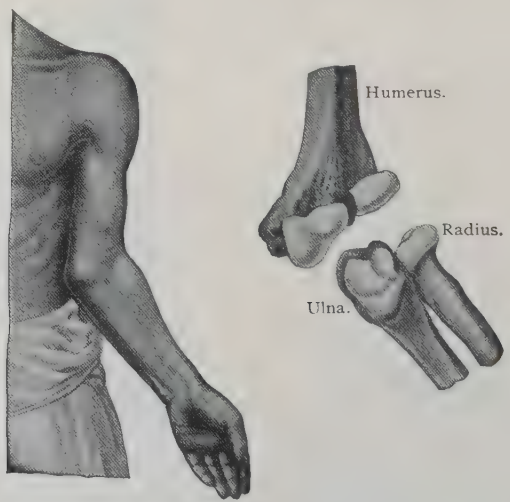


Fig. 469.—Fracture of the external condyle; union with fragment displaced upward, resulting in permanent abduction of forearm (after Helferich).

It is important that the arm and forearm are made to maintain their normal relations to each other in the sagittal plane while the humerus is

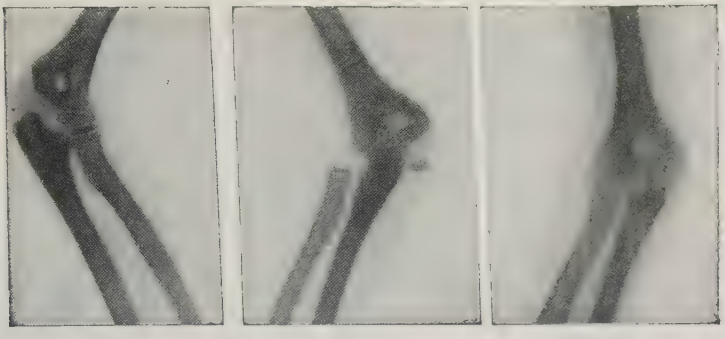


Fig. 470.—Internal epicondylar fracture.

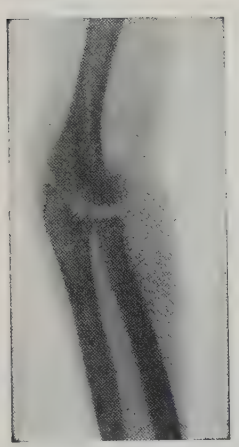


Fig. 471.—Note displaced epicondyle.

Fig. 472.—Epicondylar fracture.

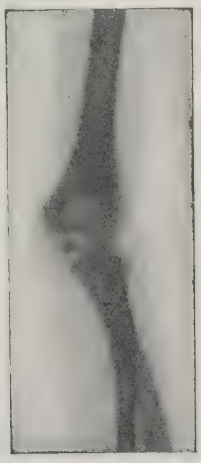


Fig. 473.—Epicondylar fracture.

Fig. 474.—Displaced fragment of epicondylar fracture with dislocation of forearm backward.

Fig. 475.—Fracture of external condyle.

Fig. 476.—Fracture of external condyle.

rotated neither externally nor internally. Thus only will a deformity of cubitus varus be avoided.

(*g*) Fracture of the External Condyle (see Figs. 469, 478, 479): Swelling over this condyle is marked. The line of fracture enters the joint. The

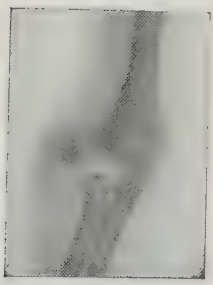


Fig. 477.—Case of fracture of external condyle. Capitellum displaced.

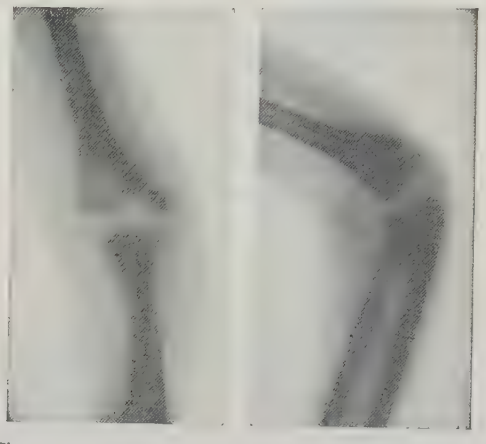


Fig. 478.—Case of fracture of external condyle with capitellum displaced.

separated fragment is the entire capitellum and sometimes the outer lip of the trochlea. Crepitus and abnormal mobility are present. The normal relations of the three bony points are disturbed. The external condyle is displaced

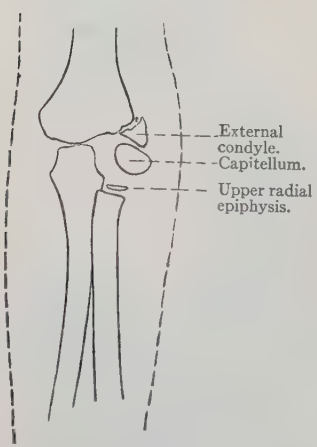


Fig. 479.—Fracture of external condyle of humerus. Child five years of age. Nucleus for capitellum seen below fragment.

Fig. 480.—Transverse fracture above the condyles of the left humerus; characteristic deformity. The anterior deformity is higher than in dislocation of the elbow.

downward and forward due to gravity, so that the normal carrying angle support vanishes with the fracture. The fractured external condyle is forced backward and upward by the hyperflexion position. The relation of the external condyle and the head of the radius is undisturbed. Lateral motion at

the elbow is present. Cubitus varus or valgus can be produced at will. The transverse measurement of the elbow is greatest on the injured side. Supination will be somewhat limited.

(*h*) Transverse Fracture of the Shaft of the Humerus Above the Condyles—Supracondylar Fracture (see Fig. 480): The line of this fracture is higher up on the shaft than the line of the epiphysis passing from epitrochlea to epicondyle. The fracture may cross the olecranon fossa. I do not believe it is necessary to separate diacondylar and supracondylar fractures in discussion. A fulness will be noticed in front of the elbow-joint, and posteriorly the point of the elbow will appear prominent. This fracture may be compound. The small lower fragment is displaced backward with the bones of the forearm; the upper fragment or shaft of

Fig. 481.—Transverse fracture above the condyles of the humerus. Same as Fig. 460.

the humerus is displaced forward, causing the fulness in the bend of the elbow (see Figs. 480–483). The three bony points maintain their normal relations. This distinguishes the fracture from a dislocation of both bones backward (see Fig. 484). Crepitus will be detected upon grasping the arm firmly above and below the elbow-joint (see Fig. 433). Recurrence of the displacement often follows its correction unless the fracture is properly immobilized. Reduction of this fracture may be most difficult. Abnormal lateral and anteroposterior mobility above the elbow-joint is found.

The *Posadas-Chutro fracture* is properly classed here. A transverse diacondylar fracture by flexion (the lower fragment being displaced forward into the bend of the elbow) complicated by a posterior luxation of the radius and ulna which if not replaced may come in time to form a false joint with the lower end of the upper fragment. A case is recorded by Ashhurst.

(*i*) Separation of the Lower Epiphysis of the Humerus: The lower epiphysis of the humerus unites to the shaft about the seventeenth year.

Fig. 482.—The deformity seen after a supracondyloid fracture of the humerus. Note that the normal bony relations of the olecranon are undisturbed (after Pedro Chutro, Buenos Aires).

It includes only the very lowest end of the humerus. The lower epiphysis of the humerus is made up of the external epicondyle, the capitellum, and

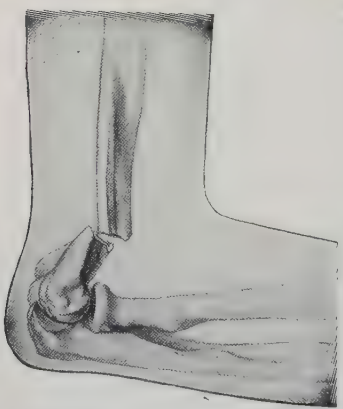


Fig. 483.—Supracondylar fracture of humerus. Elbow flexed to a right angle. Diagram to show displacement of bones.

Fig. 484.—Dislocation of both bones of the forearm backward. Elbow flexed to right angle. Diagram showing relative position of bones. Compare with Fig. 483.

the trochlea. These separate centers of ossification unite about the thirteenth year, and at about the seventeenth year they join the shaft of the bone. The epiphysis of the internal epicondyle is entirely separate from

the large, general, lower humeral epiphysis. It is, therefore, possible to have a complete separation only after the thirteenth year. The detached epiphysis is in large part if not always intra-articular. The joint cavity extends to above the coronoid and radial fossæ, while the epiphyseal line lies below this (see Figs. 442, 493).

This is a not uncommon accident. It occurs usually in children under ten years old. There is no change in the relations of the three bony points. It somewhat resembles transverse fracture above the condyles. The diagnosis is made upon the following points: The age of the individual; the history of the accident; the existence of abnormal mobility at a very low level on the humeral shaft; anteroposterior mobility very marked, lateral mobility being less marked; muffled crepitus (this term is very suggestive, and is used by Poland); a soft crepitus, comparable to the crush of a wet snowball (Eliason). The breadth of the lower end of the humeral fragment is broader than in the

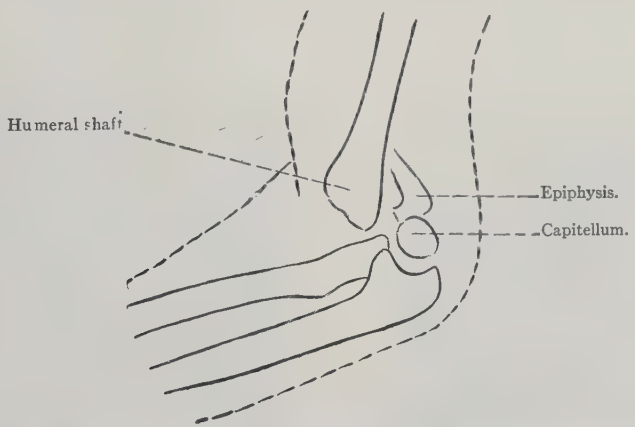


Fig. 485.—Displacement of lower epiphysis of humerus backward, with fracture of the diaphysis. Child seven years of age (*x*-ray tracing).

case of a fracture (see Figs. 485–492, inclusive). The separation may be compound. In old injuries of this kind there is usually discovered a very considerable thickening of the lower end of the humeral shaft. This is due to the deposit of new bone throughout the area of denuded periosteum.

(*j*) T-fracture into the Elbow-joint (see Figs. 494–496): The traumatism which causes this injury may be extremely slight. If the two condyles are grasped, crepitus and abnormal mobility will be detected. The relations of the three bony points will be disturbed, according as one or both condyles are displaced. The transverse measurement of the condyles will be found to be increased. There will be abnormal lateral mobility, both in adduction and abduction.

A systematic anatomical examination of injuries to the elbow under an anesthetic will overcome much of the indefiniteness that surrounds these injuries. A crushed elbow, feeling to the examining hand like a bag of bones, cannot always be accurately diagnosed, some of the details of the lesions

Fig. 486.

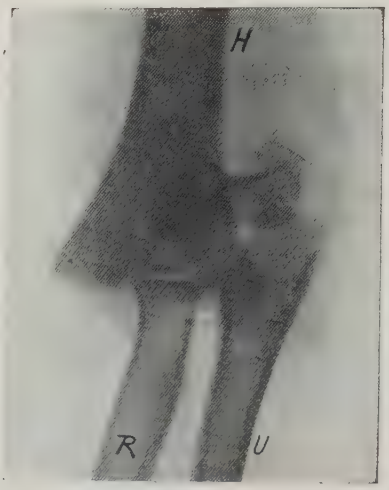


Fig. 487.

Fig. 488.

Fig. 489.

Fig. 490.

Figs. 486–490.—Separation of the lower humeral epiphysis. Illustrating varying degrees of displacement: *H*, Humerus; *R*, radius; *U*, ulna.

naturally remaining undetermined. The Roentgen ray in these doubtful cases will be of material assistance. The importance, however, of making

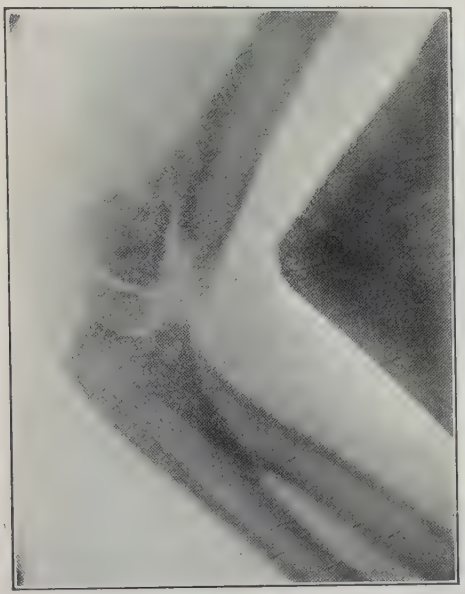


Fig. 491.—Separation of lower humeral epiphysis.

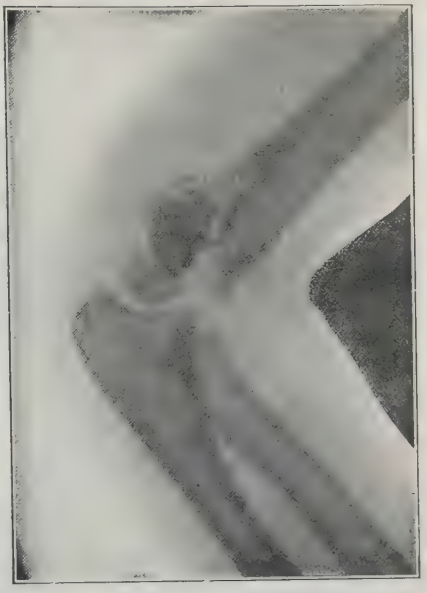


Fig. 492.—Same as Fig. 491. An attempt to approximate the fragments has been made under an anesthetic. Note the lower end of the upper fragment in the bend of the elbow ready to impede motion.

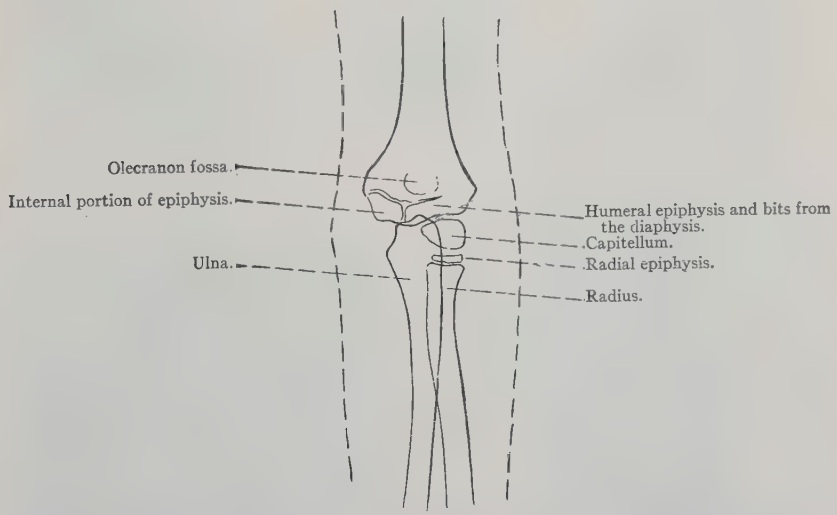
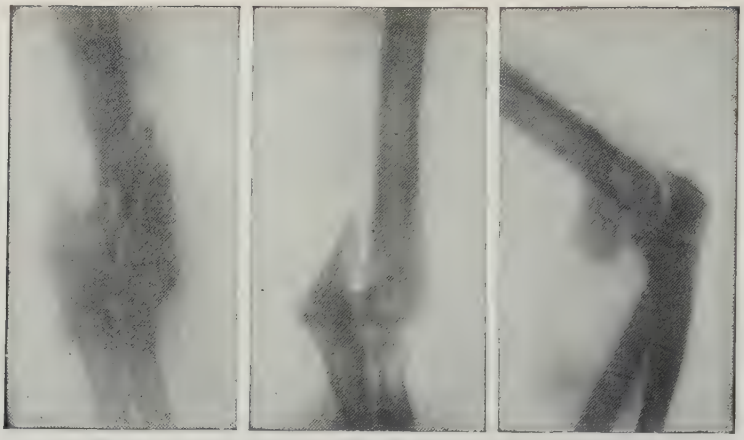


Fig. 493.—Separation of the lower epiphysis of the humerus after union. Anteroposterior view. This figure illustrates the fact that the epiphysis does not include the internal condyle of the humerus (*x*-ray tracing and see Chapter on The Epiphyses).

such a careful eliminative examination as is described, both from the point of view of treatment and prognosis, cannot be overestimated.



A B C

Fig. 494.—A, T-fracture into joint. B, C, Fracture into joint with displacement of humeral fragment.

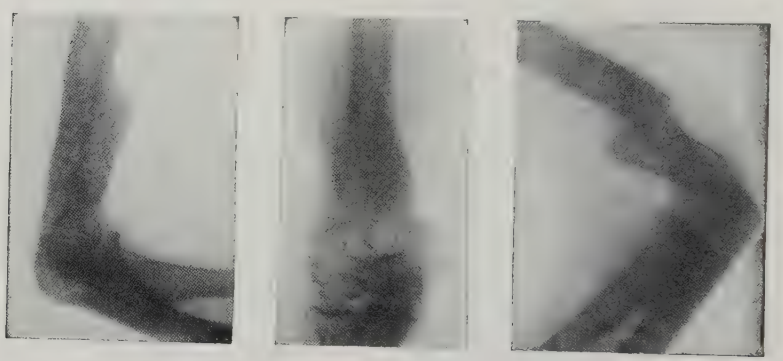


Fig. 495.—T-fracture of the lower end of the humerus.

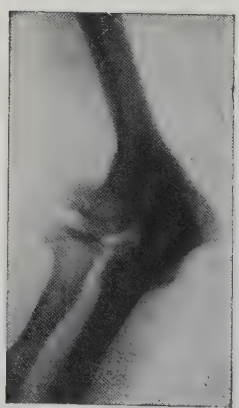


Fig. 496.—T-fracture of lower end of humerus.

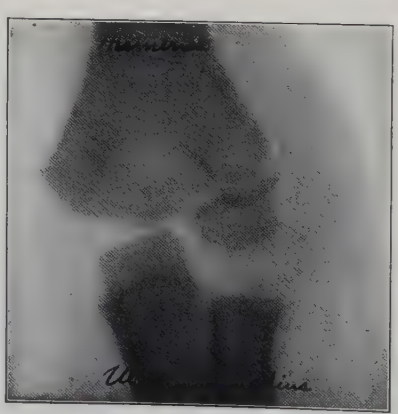


Fig. 497.—An injury to the humeral lower epiphysis on radial side.

Treatment of Fractures About the Lower End of the Humerus.—These fractures should be regarded as special emergencies. The earlier reduction can be effected, the easier is reduction. The most rapid method of removing the swelling is to restore the normal anatomical relations. The prevention

Fig. 498.—A fracture of the neck of the radius and a starting of the external part of the lower humeral epiphysis. The capitellum is displaced upward slightly.

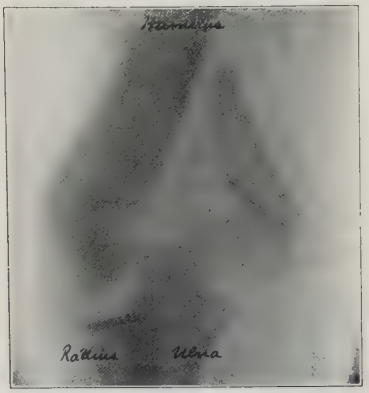


Fig. 499.—A T-fracture into the elbow-joint.

of elbow swelling lies in early reduction of the fracture. Efforts at reduction of fractures about the elbow should be made with the assistance of a general anesthetic and the employment of a fluoroscope.

Fig. 500.—A separation and a displacement backward of the lower epiphysis of the humerus.

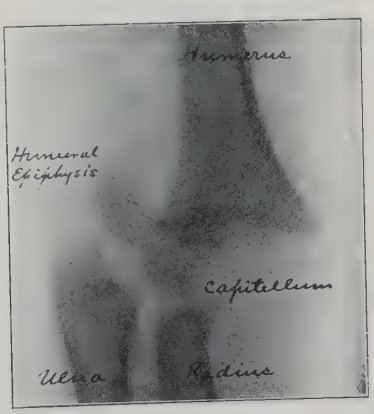


Fig. 501.—A separation and displacement inward of the lower epiphysis of the humerus.

In fractures essentially transverse to the long shaft of the humerus—*i. e.*, supracondylar fractures, separation of the lower humeral epiphysis, transcondylar fractures—the lower fragment should be regarded as an integral part of the forearm. Traction alone will fail of reduction. With the elbow firmly grasped the existing deformity is exaggerated, the fragments are un-

locked, and while making strong traction the edges are made to slide by each other; the lower fragment is then made to slide forward, the elbow being flexed. The same method of angulation is used in correcting lateral displacement.

It must always be remembered that the lower articular surfaces of the humerus are not in a straight line with the longitudinal axis of the humeral shaft (see Figs. 435, 443). The articular portion normally swings far forward at an angle of about 130 degrees (see Fig. 444). The articular surfaces point forward and downward and not merely downward, as supposed ordinarily. Consequently, the acutely forced flexed position tends to re-establish the normal relations of the lower end of the humerus and the shaft. The object of treatment is to restore the elbow-joint to its normal condition.

If the fracture when first seen is attended by very great swelling it may be necessary to temporarily support the arm until the swelling reaches its maxi-

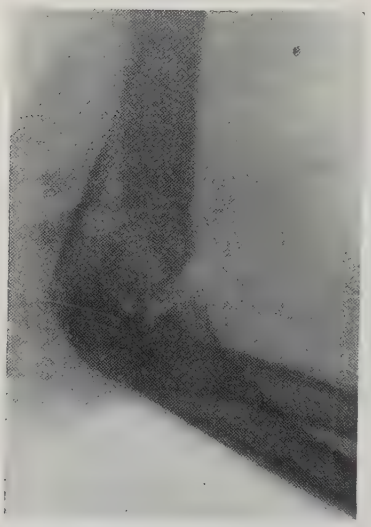


Fig. 502.—Compound comminuted fracture of elbow in a woman sixty years old (Dodd).

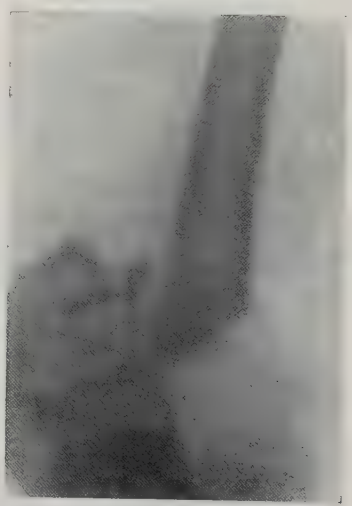


Fig. 503.—Lateral view of Fig. 502.

mum and begins to subside. The right-angle internal or anterior angular splint loosely applied is the most satisfactory for this purpose (see Figs. 520–523). The maximum swelling will have taken place after forty-eight to seventy-two hours. This temporary dressing will rarely be needed. In general, it may be stated that the arm should be placed in that position in which it is found, upon experiment with the fracture under consideration, that the fragments are best held reduced.

Fractures of the Internal Epicondyle, of the Internal Condyle, of the External Condyle, and T-fractures into the joint are best treated, as a rule, in the acutely flexed position.

The Flexed Position of the Elbow is an active force for the maintenance of reduction. Hyperflexion is perhaps a better term than the acutely flexed

position. Hyperflexion does not mean merely acute flexion; it is the most acute flexion in which the elbow can be placed without obliterating the radial pulse. The angle of flexion is from 20 to 35 degrees. The time for hyperflexion to secure the best results is not when the elbow is swollen or the

Fig. 504.—After snugging fragments together by aluminum bronze wire.

Fig. 505.—Lateral view of Fig. 504. Final result excellent functional usefulness of elbow (Dodd).

swelling is disappearing, but as soon after the fracture as the patient is seen —before any swelling.

Experimental evidence, both upon the cadaver and on the anesthetized living subject, confirmed by clinical experience extending over a number of

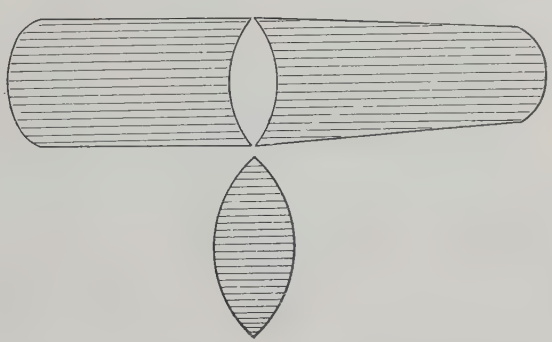


Fig. 506.—Patterns of pieces used in making the usual (soldered) internal right-angle splint, seen applied in Fig. 523.

years in the hospital and private practice of many different surgeons, demonstrates that the acutely flexed position (Smith and Jones) actively reduces and holds reduced the fractures previously mentioned. In the acutely flexed position the coronoid process in front, the trochlear surface of the olecranon behind, and the fascia posteriorly and laterally, together with

the tendon of the triceps posteriorly, hold the fragments reduced and close to the shaft of the humerus.

Method of Using the Hyperflexed Position: A general anesthetic is always necessary. The condyles of the humerus are grasped by the thumb and finger of one hand, a finger of the other hand is placed in the bend of the elbow, traction is made upon the forearm, and it is slowly flexed to an acute angle. While the forearm is being flexed, traction and lateral pressure are brought to bear upon the loose fragments of the humerus to correct existing malpositions. These manipulations will materially assist in the reduction (Fig. 507). The reduction should be checked up and facilitated by the use of the fluoroscope in every instance. The anteroposterior deformity is first reduced, the forearm is flexed, and the fluoroscope used with the arm and forearm abducted and in the plane of the supine patient's body. If this view is good the limb is brought to the patient's side with the hand on the shoulder of the injured side and a look taken. Should there be lateral displacement the forearm is extended to about a right angle and the lateral deformity corrected (Eliason).

In fractures of the internal condyle it is desirable to have the elbow hyperflexed, but the forearm should be *pronated* (Cohn), relaxing the pronator

Fig. 507.—Supracondylar fracture of the humerus. Method of reduction before applying retentive splint. Countertraction on upper arm. Traction on condyles of humerus with right hand; backward pressure with thumb of left hand. Also illustrative of method of beginning acute flexion.

radii teres. In fractures of the external condyle the position of greatest stability is one of hyperflexion and *supination*. Fractures requiring the acutely flexed position that cannot be well reduced by traction manipulation and this acutely flexed position should in most instances be reduced by operation.

The degree of flexion will be determined by the obstruction offered by the local swelling and the effect upon the radial pulse of the flexion. If the swelling is great, or is likely to increase very much, then the degree of

flexion must be less than when there is no swelling. In the bend of the elbow, to prevent chafing, is placed a piece of gauze upon which has been dusted a dry powder.

This acutely flexed position is maintained by an adhesive-plaster strap, 3 inches wide, passing about the arm and forearm (Fig. 508). This strap should be placed upon the upper arm as high as the axillary fold, and upon the forearm just above the styloid of the ulna. A piece of linen or compress cloth (cotton cloth) is placed under the forearm and hand where they would come in contact with the skin of the chest. This should be pinned so as not to slip from position. The arm thus flexed is supported by a swathe sling (Fig. 509) made of cotton cloth, 15 inches wide, folded three times, and long enough to extend twice around the body. This is applied as illustrated (Figs. 510–512). The elbow is held to the side by pinning a strip of compress to the swathe at the elbow and posteriorly (see Fig. 511). Ashhurst's method of maintaining flexion and supporting the upper extremity is effective and comfortable (see Figs. 514–516).

Fig. 508.—Position of flexion. Note broad adhesive strap, *protected posteriorly*, to prevent cutting. The cravat sling to be applied over this.

Fig. 509.—Left elbow in position of forced flexion. Gauze in bend of elbow. Thin axillary pad. Pad under hand and wrist. Gauze protection under forearm, held by safety-pin from slipping. Adhesive plaster maintaining flexion. *Skin protected on upper arm by gauze compress from cutting of adhesive plaster.*

Precautions in Using the Acutely Flexed Position: The arm is inspected each day for the first week. It is necessary to note whether, with the onset of swelling, the flexion of the arm should be diminished, and whether with diminution in swelling the flexion may be increased with safety. The radial pulse should be present as the flexion is increased, so as to avoid

Fig. 510.—Applying figure-of-8 cravat to flexed elbow (after Lund).

Fig. 511.—Strap from elbow to cravat to prevent abduction of flexed elbow.

Fig. 512.—Fastening figure-of-8 cravat over folded compression on opposite side of chest. Elbow region open to inspection.

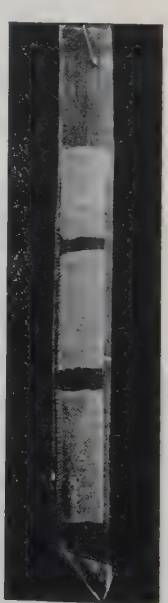


Fig. 513.—Adhesive-plaster strip showing bits of gauze arranged so as to protect skin from plaster without impairing efficiency of the plaster.

Fig. 514.—Dressing to maintain elbow in hyperflexion, first stage. No adhesive plaster is used in this dressing (Ashhurst).

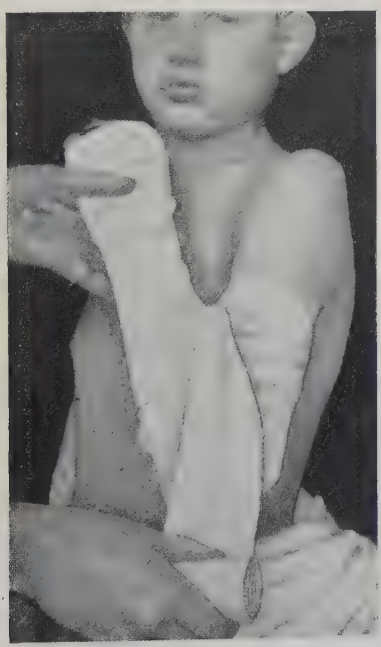


Fig 515.—Dressing to maintain elbow in hyperflexion, second stage (Ashhurst).

Fig. 516.—Dressing to maintain elbow in hyperflexion, completed (Ashhurst).

compression of the vessels at the bend of the elbow. There should be no pain associated with this acutely flexed position. A certain amount of discomfort may be complained of. Real pain will be indicative of too great pressure, and if it is present, the forearm should be less acutely flexed.

A B

Fig. 517.—Fracture of the shaft of the humerus. Plaster dressing in the lateral hyperflexed position, see Fig. 518, Position A. The figure on the right shows an ordinary method of immobilization against the chest wall, see Fig. 518, Position B. (Eliason, Jour. Amer. Med. Assoc., June 14, 1924).

Chafing should be looked for at the bend of the elbow, under the forearm and hand, and on the chest, where, if necessary, fresh powder and compress cloth should be placed. The edge of the adhesive plaster may cause chafing

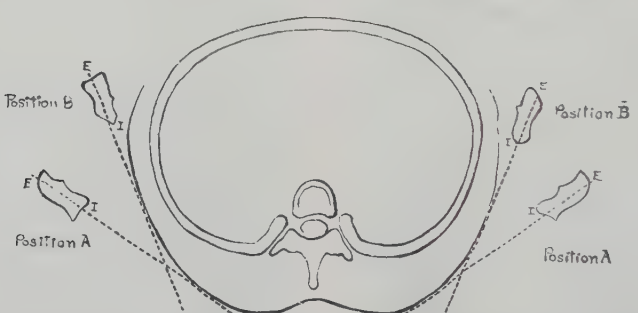


Fig. 518.—A diagram of a cross-section through the trunk and the arms at the level of the condyles of the humeri (Position A). The normal one is retained in the lateral hyperflexed position. Position B is the one assumed when the forearm rests in the chest. E and I mark respectively the external and internal condyles of the humerus. (Eliason, Jour. Amer. Med. Assoc., June 14, 1924.)

of the skin upon the posterior surface of the forearm and upper arm. It may be necessary to place beneath the plaster small carefully folded compresses of cotton cloth to protect the skin (see Figs. 510, 513).

Later, in changing the adhesive plaster, the skin may be washed with alcohol and then with soap and water, to the great comfort of the patient. The alcohol removes all adhesive plaster sticking to the skin. If the adhesive plaster chafes the skin, as it so often does in children, it will be necessary to place a bit of gauze under the adhesive-plaster strips, leaving enough of the sticky side of the plaster uncovered to catch the skin and thus keep it from slipping entirely loose. The carrying angle of the arm will be preserved if the fragments are approximately reduced; it cannot be maintained otherwise. The acutely flexed position reduces the fragments in the fractures under consideration; therefore it will preserve the carrying angle.

Eliason has directed attention to the fact that the intercondylar planes of the humeri pass posteriorly, meeting behind the spine. The arms hang naturally at the sides so that the external condyles are anterior to the internal condyles (see Fig. 518). In supracondylar fractures, to avoid rotation

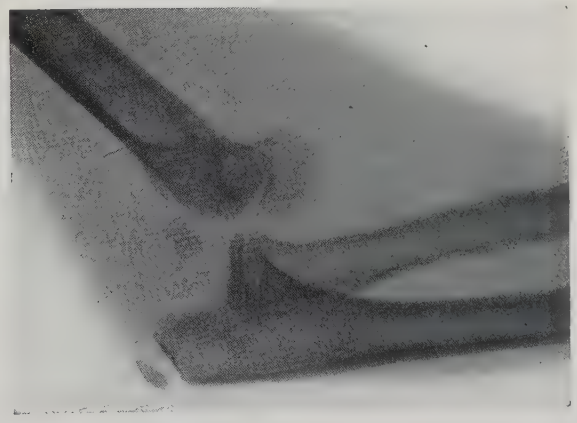


Fig. 519.—A simple dislocation of the forearm backward. Rather rare in children. Note the various centers of ossification. This was replaced without an incision. It is important in this injury to be positive that the epiphyseal centers are in their proper places after reposition.

of the lower distal fragment inward on the humeral shaft, Eliason believes that, in employing the acutely flexed position, the hand should be carried to the shoulder of the injured side. The humerus is allowed to maintain its natural lateral position (see Figs. 517, 518). Thus will be avoided disturbing rotation deformities. This is a valuable suggestion of Eliason.

Transverse Fracture of the Shaft Above the Condyles.—There is usually an overlapping of the fragments. This is evident in the backward displacement of the lower fragment and forearm and in the forward displacement of the upper fragment (see Fig. 541).

It will be necessary in order to effect reduction of this fracture to make, with the aid of an assistant, hyperextension of the elbow, countertraction and pressure backward upon the upper fragment, while traction and a forward pull are made upon the lower fragment by grasping the arm above the condyles (see Fig. 507). The periosteal separation from the shaft of the humerus is the hinge on which the distal small fragment hangs (Thomas).

The *internal right-angle anterior splint* at first, while there is considerable swelling of the elbow region, best holds this fracture, for it exerts continuous

Fig. 520.—Fracture of the elbow. Application of the internal right-angle splint or anterior splint. First strap already applied. Manner of holding splint and arm as the forearm is flexed up to the splint (see Fig. 521).

pressure backward upon the upper fragment and prevents displacement (Figs. 520, 521). This internal right-angle splint has a distinct use in in-

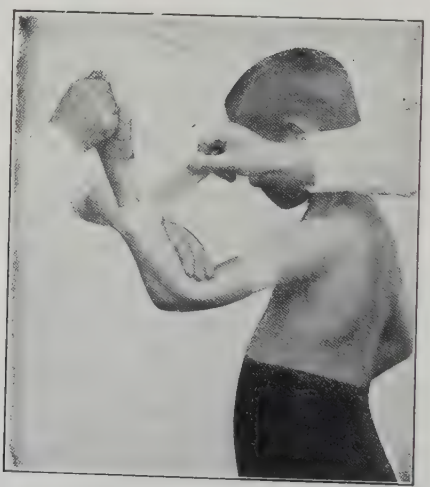


Fig. 521.—Fracture of the elbow. Application of the internal angular or anterior splint. Placing second strap. The angle of the splint is crowded into the bend of the elbow (see Fig. 520).

juries to the elbow. Satisfactory use of this splint is no more difficult than is the employment of any splint. It is a valuable part of the surgeon's armamentarium. The splint is padded with sheet wadding and applied as illus-

trated. Two straps are needed upon the forearm to hold this splint in good position (Figs. 522, 523). The strap at the wrist should be so applied that there is no pressure upon the styloid process of the ulna. Long-continued pressure upon this bony process would cause a pressure sore. In applying the adhesive plaster it is wise to apply it so loosely that there is no undue pressure upon the arm, which might retard the circulation. The arm is then covered with a roller bandage of sheet wadding over which is placed a roller bandage of cheese-cloth. This should be applied smoothly and firmly from the hand to the upper end of the splint. As the swelling about the elbow begins to subside, pads of cotton cloth (compress cloth) may be placed at each side of the olecranon below each condyle. The pressure of a frequently renewed bandage on these pads will hasten the disappearance of the swelling. It is important to avoid the forward and backward deformity in treating this fracture (see Figs. 524–526). Sometimes it may be possible,

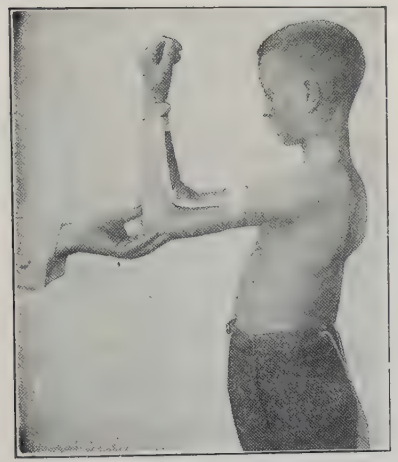


Fig. 522.—Two straps insufficient to hold elbow in internal right-angle or anterior splint. Splint has slipped away from the bend of the elbow.

Fig. 523.—Third strap is necessary to hold the splint close to the flexed elbow.

without causing too great tension at the elbow from the swelling, to place the elbow in a position of acute flexion instead of at a right angle. Thus would be assured in certain types of this fracture a more positive hold on the lower fragment. Even if the acute flexion is impossible at first, later it may more safely be employed.

Dislocation of Both Bones of the Forearm Backward.—If there is no tendency to displacement after reduction is accomplished, the right-angle position with internal splint is the best treatment. If, on the other hand, there is a tendency to displacement, the acutely flexed position will be the best for the arm because in case the coronoid process is broken it will insure its close approximation to the ulna.

Separation of the lower epiphysis of the humerus will be best treated in the right-angle or hyperflexed position, the same as for a fracture of the humerus above the condyles.

Fracture of the neck of the radius is best treated by the internal or anterior right-angle splint (see Figs. 520, 521). At times the position of acute flexion with the forearm supinated is desirable.

Fracture of the olecranon is discussed elsewhere (see p. 404).

The After-care of Injuries to the Elbow.—The reapplying of splints and of apparatus should be done often enough to be sure that they are efficient, and that there is no undue swelling of the arm and hand or too great pressure upon the arm. A perfect result is likely following careful treatment of fractures of the elbow in childhood. By a perfect result is meant

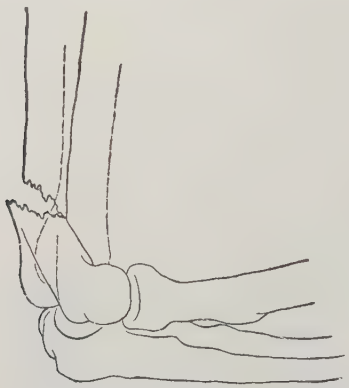


Fig. 524.—Supracondylar fracture. Obliquity of the line of fracture from behind downward and forward. Diagram showing deformity with elbow flexed and little sliding of fragments.

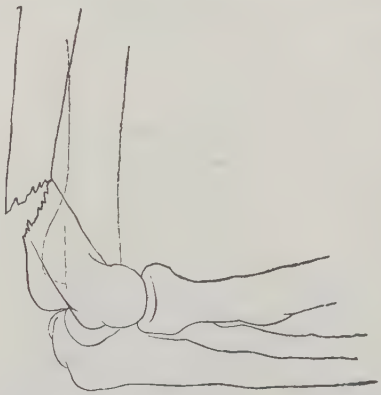


Fig. 525.—Supracondylar fracture. Obliquity of the line of fracture from above downward and backward. Diagram showing tendency to posterior deformity if acute flexion of forearm is attempted.

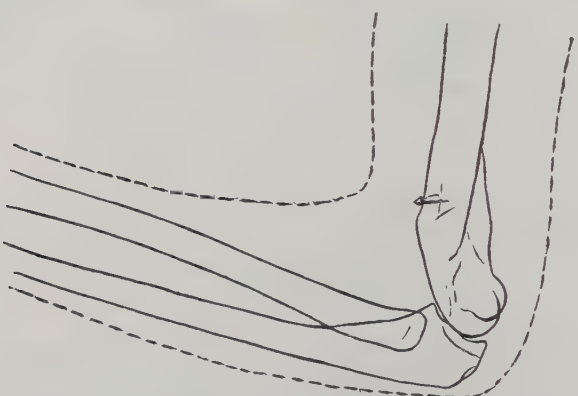


Fig. 526.—Supracondylar fracture with slight anterior displacement with wire suture. Recovery, with slight anterior bending of fragments. Wire seen *in situ* (*x*-ray tracing). (Massachusetts General Hospital, 1077.)

a full and normal range of motion without limitation and without deformity, that is, no varus or valgus deformity.

Such early mobilization of the elbow is desirable as will not interfere with the maintenance of reduction. Neuhof and Wolf have demonstrated the wisdom of this early motion. Those opposed to early active motion feared

displacement of fragments and excessive callus. Early mobilization and massage must be painless. The fourth day it may be begun. The treatments consist in the beginning in gentle stroking, massage of the arm, and

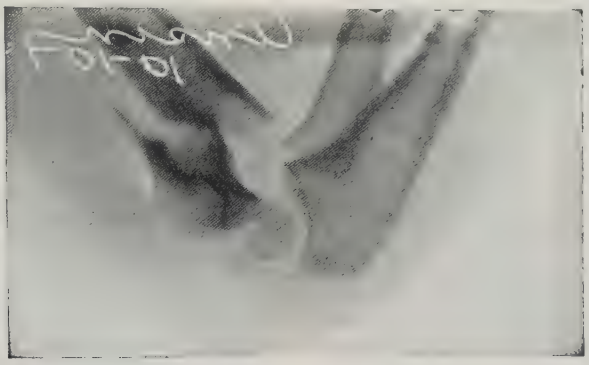


Fig. 527.—Fracture through condyles of the humerus. Anterior displacement could not be completely corrected. Open incision and replacement by direct leverage indicated (Dodd).

active movements at the elbow in slight extension and flexion. All sudden movements are avoided. The elbow is always to be supported during

Fig. 528.—Separation and backward displacement of lower epiphysis of humerus. Note stripping of periosteum off posterior surface of shaft. Right-angled splint.

treatment and is fixed in hyperflexion after each treatment. Massage and mobilization are applied daily for a few moments.

The length of time the elbow is kept in the hyperflexed position depends upon several things: the union of the fracture, the type of fracture, the pain-

lessness of the movements possible. The dressing is rarely needed for more than three weeks.

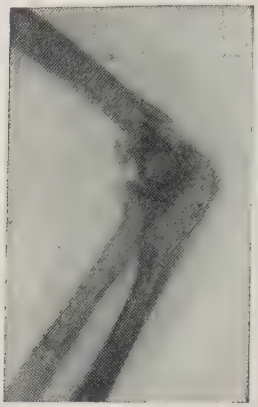


Fig. 529.—Flexion fracture, lower end of humerus.

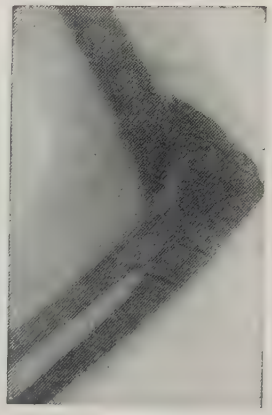


Fig. 530.—Extension fracture of humerus. Note bad position of lower end. Flexion will be impaired if unreduced.

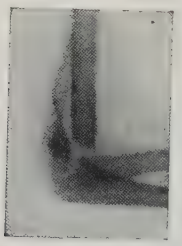


Fig. 531.—Extension fracture. Note stripped-up periosteum.

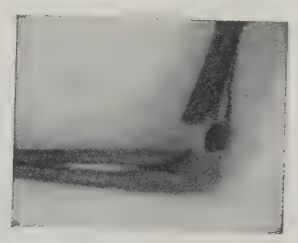


Fig. 532.—Extension fracture. Note stripping of periosteum from posterior part of humerus.

Fig. 533.—Separation of lower humeral epiphysis. Projection of upper fragment into bend of elbow.

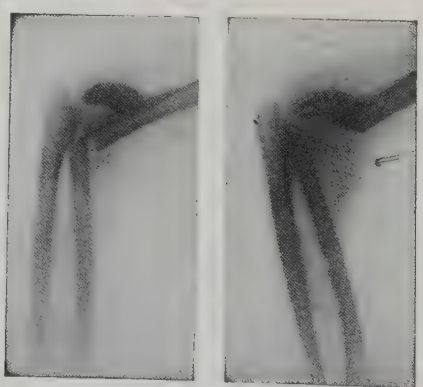


Fig. 534.—Fracture of lower end of humerus. Anterior projection of upper fragment.

Never should a recent fracture of the elbow be treated by a general anesthetic and forced passive movements. Never should painful active or passive movement be made in a recent fracture of the elbow.

If a child is given a proper sized wheelbarrow to play with while convalescing from an "elbow fracture" the result will be improved. The child finds after a few days that progress is made without pain by hauling loads in the wheelbarrow rather than by the movements intermittently made by the doctor or the masseur (Ochsner).

Fig. 535.—Fracture of the lower end of the humerus with displacement backward of lower fragment carrying forearm with it.

Fig. 536.—Same as Fig. 535. Reposition accomplished through an incision and by leverage. Note especially the apparent, not real, projection of the tip of the lower end of the inner condyle forward. This will not interfere with perfect functioning of the elbow.

Massage to the hand, wrist, forearm, elbow, and upper arm before the primary swelling has begun to subside is of great value. It should be given at first without disturbing the apparatus and the retentive adhesive plaster. Given every day or every other day it will accomplish considerable in maintaining the integrity of the muscles of the part. The employment of a professional masseur is not necessary, but is desirable. The physician should give the massage or instruct a competent person how to give it.

Fig. 537.—An irregular transverse fracture of the lower end of the humerus just above the epiphyseal line. Note sharp serrations. A most difficult fracture to replace. (See Fig. 538.)

Fig. 538.—Same case as Fig. 537. Note practically perfect reposition of the fracture. This was accomplished by an external condylar incision and leverage of the lower fragment into position assisted and confirmed by digital palpation. An incision and leverage without permanent metallic pegging or suture is very sure in this type of fracture.

Omission of Splint or Retentive Apparatus: This should be tentative and gradual after union is known to be firm —in the third week. At this stage the carrying of dumbbells, pails, or baskets filled with sand, and the doing of certain gymnastic movements with the injured arm will be

Fig. 539.—Fracture of the lower end of the humerus close to epiphyseal line. The contour of the lower end of humeral fragment indicates that bone is broken above epiphysis. Note stripping of periosteum from posterior surface of humerus. Absolutely impossible to reduce this fracture without an incision and the removal of new bone between periosteum and shaft of humerus.

Fig. 540.—Lateral view of same case seen in Fig. 539.

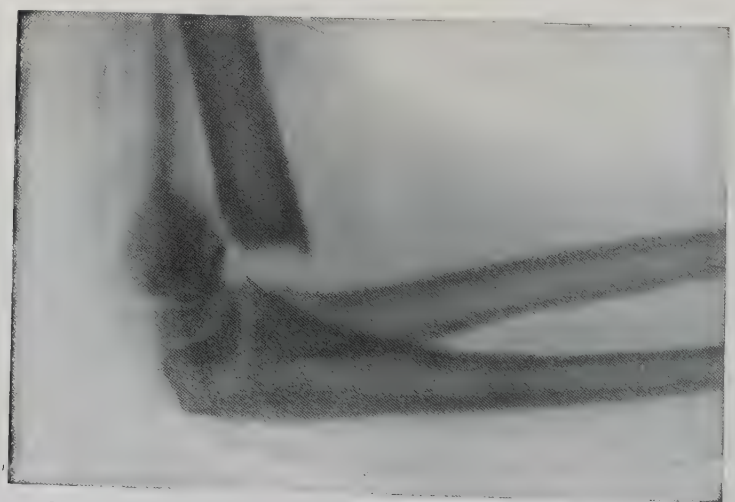


Fig. 541.—Separation of the lower humeral epiphysis with fracture of the shaft. Displacement of the forearm backward and of humeral shaft forward. It is often impossible to reduce this fracture without incision. Note the posterior periosteal separation in the shaft of the humerus.

of material aid. All violent exercise of the part is to be avoided. That amount of exercise may be allowed that leaves the arm moderately tired.

A fatigue that is not recovered from within a half-hour's rest is excessive.

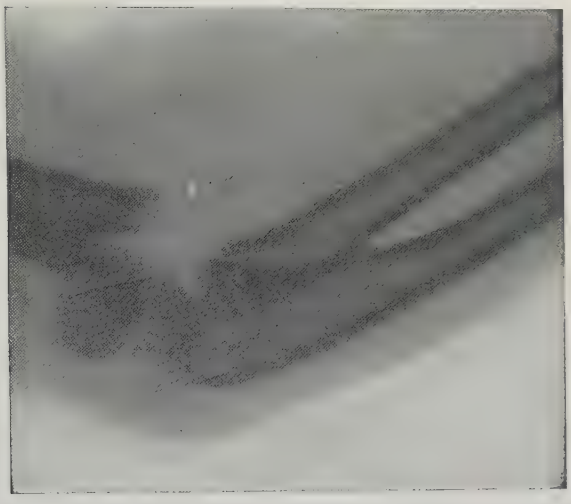


Fig. 542.—Separation of the lower humeral epiphysis. Before operation. Note the forward projection of the lower end of the fragment of the humerus impeding flexion.

Up to the time of the introduction of the acutely flexed position in the treatment of fractures at the elbow the movement most easily lost and with greatest difficulty regained was that of flexion. By the use of the acutely

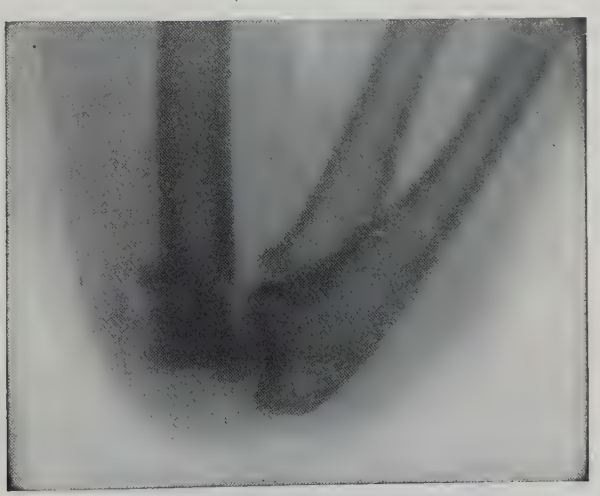


Fig. 543.—Separation of the lower humeral epiphysis. After operation. Note the normal angle of flexion. Over one year following the open incision and reduction, functions and movements of elbow and forearm are normal. Same case as in Fig. 542.

flexed position in suitable cases the prognosis has improved remarkably in this respect. Now all of flexion is ordinarily preserved, and the more easily acquired extension is obtained as usual, so that the prognosis as to motion

in these cases is good. Although anatomically perfect results are not always obtained, most fractures of this region recover with a useful arm. These

Fig. 544.—Supracondylar fracture of the humerus. Note the inability to extend the fingers or completely flex which might follow too prolonged immobilization and absence of early massage and passive motion. Injury to the median nerve (after Pedro Chutro, Buenos Aires).

Fig. 545.—Injury to the elbow-joint: Appearances following fracture of the external condyle of the humerus (after Pedro Chutro, Buenos Aires).

fractures of the elbow region should be kept under observation for at least four months. It is wise to treat such cases until all that can be achieved

toward a restoration of function has been accomplished. Between 80 and 85 per cent. of perfect results may be expected following the acutely flexed position in fractures of the elbow-joint in children.

The acutely flexed or hyperflexed position by its anatomical mechanism maintains the fragments in place after reduction has been secured, and the early active mobilization and massage serve to secure motion at the joint involved in a large proportion of the cases thus treated.

Ashhurst has consistently employed this treatment, as have Neuhof and Wolf, with the record of a considerable number of cases. Others are using this method with equally satisfactory results.

Fig. 546.—Supracondylar fracture of the humeral shaft. Note the deformity at and above the elbow (after Pedro Chutro, Buenos Aires).

Fig. 547.—Injury to the elbow-joint: Appearances following T-fracture of the lower end of the humerus. Displacement of ulna inward (after Pedro Chutro, Buenos Aires).

At the time of the first examination of the elbow the nature of the injury and its seriousness should be explained carefully to the patient or his friends. A guarded outlook should be expressed, particularly with reference to the function of the joint. Some limitation of motion may exist after all that is possible has been done (Fig. 553). How much limitation of motion will exist it is impossible to state. There may be no limitation whatever. The patient and his friends should be encouraged with the statement that just as great usefulness of the elbow-joint will be obtained as is consistent with the character of the injury. The importance of an injury to the elbow-joint demands of every physician a painstaking anatomical examination

with the aid of an anesthetic, careful attention to minute details in the initial treatment, and intelligent solicitude in the after-care.

Caution: Active massage, passive motion, movement under an anesthetic all tend to cause ultimately swelling of the elbow, exuberant callus, pain, and a loss in the final degrees of motion at the joint.

For Fractures of the Elbow-joint in Adults see p. 349.

REMARKS ON ELBOW INJURIES. LIMITATION OF MOTION AT THE ELBOW

Following trauma there may be a change in the axis of one or more of the articular surfaces of the elbow-joint, or there may result a free loose fragment so displaced as to act like a wedge between articular surfaces. In children a fracture of the *external condyle* resulting in a displacement of the capitellum will produce a limitation of movement unless a perfect restitution is made. The normal relations of the capitellum and the midplane of the

Fig. 548.—Supracondylar fracture of the humerus in a child six and a half years old. *x*-Ray taken June 21, 1921. (W. Rowley Bristow, British Journal of Surgery, vol. x, p. 475.)

humeral shaft to the sigmoid cavity and to the lower end of the shaft of the humerus have been stated. Failure to reduce the displaced capitellum means a change in carrying angle and limitation of motion. It may be wise to remove this epiphysis if motion of the joint is at stake. Keep in mind the axial plane of the shaft and the epiphysis (Cohn).

Fractures of the coronoid process, of the internal condyle, and of the head of the radius may be associated with a free fragment, which, if it cannot be replaced and maintained in position, should be removed.

Fractures of the upper third of the shaft of the ulna should be carefully reduced. If left unreduced the shaft of the ulna will swing so as to produce a smaller carrying angle. If this occurs together with a slight flexion of the upper fragment of the ulnar shaft the relations of the olecranon sigmoid cavity and the lower end of the humerus will be so altered as to cause a limitation

of flexion at the elbow (Cohn). This limitation of flexion and loss or diminution of the normal carrying angle will be a distinct handicap. *Open operation* may be needed to hold reduced this upper end of the ulnar fracture.

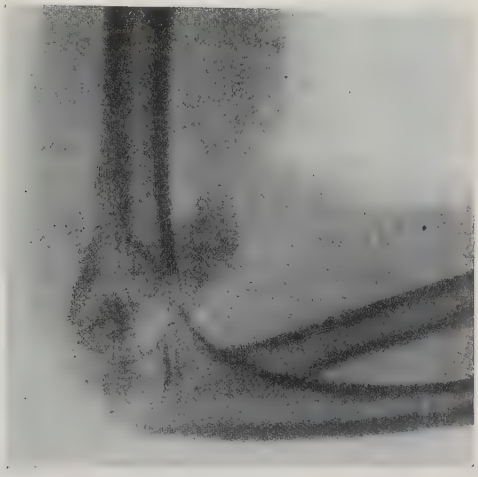


Fig. 549.—Same case as Fig. 548. *x*-Ray taken July 17, 1921. Three weeks after the accident. Note the shadow anterior to the humeral shaft and in brachialis anticus muscle. (W. Rowley Bristow, British Journal of Surgery, vol. x, p. 476.)

Only absolutely necessary time should be permitted to elapse before reduction of an elbow fracture is attempted. Every hour of delay is handicapping the patient's ultimate functional recovery.

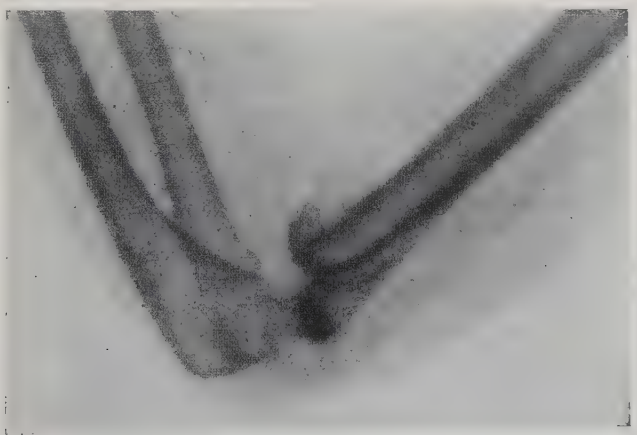


Fig. 550.—*x*-Ray of same case as Fig. 549 taken August 30, 1921. After absolute rest in the flexed position the shadow of new bone is smaller, more opaque, and better defined than in Fig. 549. (W. Rowley Bristow, British Journal of Surgery, vol. x, p. 475.)

Following elbow fractures there may be a cubitus valgus or a cubitus varus deformity. The cubitus valgus deformity is less disabling than is a cubitus varus deformity (MacAusland).

Absolutely perfect anatomical reposition should be sought in fractures entering or indirectly involving the elbow-joint. A child has nothing to lose in time and everything to gain in a perfect joint.

Fig. 551.—*x*-Ray (same case as Figs. 548-550) taken November 16, 1921. Voluntary flexion and extension was permitted, but guardedly, five months after the accident. Note great decrease in new bone formation. Motion was free, controlled, and painless from full flexion to a right angle. (W. Rowley Bristow, British Journal of Surgery, vol. x, p. 477.)

Study the normal elbow-joint. Study the epiphyseal development. Study the chief disabilities following injury to the elbow, both the immediate and the remote.

Fig. 552.—Same case as Fig. 551. Final *x*-ray taken April 2, 1922. Ten months after the accident the arm was practically normal. Motion at the elbow was full and controlled. The *x*-ray shows further decrease in the new bone shadow.

Study the various compensatory possibilities in injuries to this region in order to intelligently care for unfortunate cases, who, failing to receive

adequate early and immediate treatment, seek relief from handicapping terminal conditions.

Functional usefulness *is* important. Anatomical position may be of as great importance in this part of the body.

MYOSITIS OSSIFICANS[1]

Myositis ossificans is the term applied to the more or less circumscribed formation of bone tissue in muscle tissue. The circumscribed form is of interest to the surgeon because of its association with fractures and dislocations. The occurrence of bone tissue in clean incised wounds of various parts of the body away from all and any connection with bone tissue and periosteal tissue (as in abdominal wall incisions) certainly suggests that bone can form as the result of metaplasia of connective tissues containing no osteogenic elements (see chapter on Repair of Bone).

Etiology.—It is very generally believed that the myositis ossificans associated with fractures and dislocations is due to the stripping of the periosteum from the bone or bony fragments. This is probably true even though the shadow of the new bone mass appears to be disconnected with the shaft directly—an osteogenesis of avulsed periosteum.

The occurrence of myositis ossificans is most commonly seen following posterior dislocation of the elbow. The new bone is so situated that it causes considerable disability, interfering with flexion and extension of the elbow. It is a fact that new bone is more likely to appear in cases which are reduced early and satisfactorily. It is less likely to occur in unreduced dislocations, although 2 cases are recorded. It is not unusual to find a bony growth in the belly of the brachialis anticus muscle following elbow injuries. The bony growth increases rather rapidly. After attaining its maximum size it remains quiescent and gradually subsides, sometimes disappearing completely (see Figs. 548–552, inclusive, Bristow).

Roentgen-ray Appearances.—In the early stages the shadow is not homogeneous, but contains lighter and darker areas. As ossification proceeds lines varying in width form, which, passing transversely and obliquely, bound and separate the darker areas. As the density of the shadow increases definite connection with the bone may be seen, the density of this connecting shadow usually corresponding with that of the soft parts. The bony trabeculæ correspond to the direction of the muscle-fibers within which the bony mass lies and is developing. The shadow seems to be gradually compressed, made smaller. The slowness of the mass in reaching its greatest density is in marked contrast with its rapid initial development.

Symptoms.—There will be the associated symptoms of the injury itself plus the development of a hard painful tender swelling over the anterior cubital space (bend of the elbow) in the brachialis anticus muscle area.

Differential Diagnosis.—In the absence of a traumatic etiology it may be most difficult to distinguish between a myositis ossificans and an ossifying periosteal sarcoma. Of course, as Lewis points out, a traumatic history does

[1] Lewis, Jour. Amer. Med. Assoc., vol. 80, May 5, 1923, p. 1281.

go with a periosteal sarcoma. Both occur in young people and the consistency may be the same. The Roentgen-ray findings will finally determine the differences between the two. If there is doubt after careful study of the *x*-ray, a histological examination of a bit of the tissue should be made, especially if a question of amputation is under consideration. The rate and the subsidence of the development of myositis ossificans is very characteristic; the sarcomata (osteogenic) make a progressive and rapid growth with no recessions or cessations of any sort.

Hematoma in muscle and muscle callus therein, an interstitial syphilitic process involving muscle, may be confused with the real myositis ossificans. A hematoma is discrete, separate from the parts about. The myositis ossificans will exhibit at some stage of its development an attachment, even though small, to what appear to be tiny periosteal tabs or shreds of tissue.

Treatment.—The tendency of myositis ossificans to recede should indicate, as it does, that attempts at joint movements before this time of recession has arrived is unwise. If the new bone continues to diminish in bulk it may finally spontaneously disappear (see Fig. 552). If it does not disappear and has ceased to grow smaller and is causing limitation of motion at the joint or is painful, operation for its removal may be properly considered. If the mass is removed at the time of the cessation of its growth activity, recovery will be uneventful. If by chance operative removal is done prior to the cessation of its growth activity a stimulation of the parts to renewed bone formation may result.

Painter[1] studied 339 cases and found in his own group that the brachialis anticus muscle was involved in all, and that after excision of the mass perfect functional results were obtained.

Shulz[2] thinks it is wise to wait until the osteoma is well defined, capsulated, and independent of the skeleton before operation is undertaken.

VOLKMANN-LESER CONTRACTURE

A complication of elbow-joint and forearm fractures. By Volkmann's contracture is understood a contraction or flexion of the fingers and wrist, which appears rapidly, with loss of power in the muscles of the forearm, usually following injury to the region of the elbow or forearm in young children (Dudgeon).

Leser[3] describes the clinical manifestations of Volkmann's ischemic paralysis as follows: Shortly after the constricting bandage is applied to the forearm the hand begins to swell and there is severe pain. The patient may complain of numbness or paresthesia of the fingers. The pain and swelling may develop so rapidly that the bandage is removed in an hour. If the bandage is removed only after twenty-four hours, then the fingers show marked contracture and the muscles of the forearm feel hard and stiff. Not the slightest active

[1] Boston Medical and Surgical Journal, July 14, 1921, 165, 45.
[2] Prenza méd. Argentina, August, 1923, p. 186.
[3] Saml. Klin. Vortr., 3208, 1884.

movement is possible and attempts at passive movement of the fingers cause great pain.

Soon after the removal of the bandage, often within an hour, a marked swelling in the muscles of the forearm begins. This acute inflammatory reaction in the muscles reaches a maximum in about twenty-four hours and then gradually subsides and a marked contracture of the muscles follows.

Obviously various theories as to the cause of this contracture have been advanced. That circulatory changes or nerve damage were the etiological factors concerned have been maintained. Brooks has studied the etiological factors carefully and experimentally, and I quote from his valuable paper[1]:

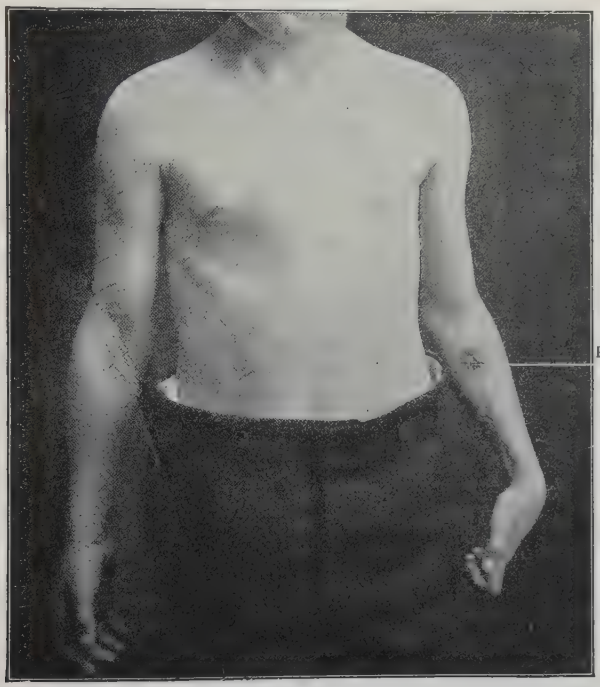


Fig. 553.—Volkmann's contracture. Illustrating the evil result following too great compression of the forearm by ordinary wooden splints. Note cicatrix below elbow on the anterior surface of the forearm. Note permanent deformity of hand due to involvement of muscles and nerves in degenerative changes from pressure.

From clinical observations there appears to be such a thing as a paralysis of muscles following an obstruction of the blood-supply to these muscles, and the paralysis may be independent of injury to the nerve trunks.

Brooks undertook a series of experiments to determine the effect of the obstruction of the circulation of blood on the function of the extremity, particularly as it concerns muscle.

From these studies it seemed that although muscles stand better than skin a continued diminished blood-supply, they stand less well a temporary absence of arterial blood.

[1] Archives of Surgery, vol. v, 1922.

The permanent occlusion of a large artery is not followed by acute inflammatory disease. Anemia and inflammation are incompatible pathological processes.

Any condition, therefore, which develops within twenty-four hours or forty-eight hours, and which is characterized by heat, swelling, pain, and a subsequent fibrosis cannot be the result of permanent occlusion of an artery.

The pathological process following the marked obstruction to venous return of blood from tissues in which the arterial supply is not obstructed is of the nature of an inflammatory, rather than a degenerative, process.

Degeneration is present, a selective necrosis of parts of muscle. The processes of inflammation and repair completely overshadow the degenerative changes. The muscle mass involved is transformed into a mass of fibrous tissue. This process sets in almost immediately after the venous occlusion and progresses with rapidity in the affected muscle, leading, of course, to an early loss of function and to contracture.

That the classic picture of Volkmann's ischemic paralysis could only be explained on the basis of acute venous obstruction would seem quite clear. Every case of contracture following the application of a tight bandage, tourniquet, plaster cast, plaster splint is referred to as Volkmann's ischemic contracture. Undoubtedly some of these cases are due to purely local pressure necrosis analogous to the decubitus ulcer or pressure sore on the heel. Brooks records a case in point of pressure of wooden splints on the forearm and hand causing a pressure necrosis with subsequent contractures.

In those instances in which a bandage or splint is applied to an extremity presumably never so tight as to obstruct immediately and completely the circulation distal to the constriction, and in which there follows in the course of a few hours great pain and local cyanosis which make the constriction no longer bearable, and in which removal of the splint is followed by swelling, heat tenderness, and a rapidly developing contracture, one is forced to assume that the etiological factor is an acute venous obstruction, which can be and has been so easily reproduced experimentally.

This terribly deforming contracture may be prevented ordinarily by the attending physician thoughtfully caring for the splints commonly used in fractures of the upper arm and forearm.

If splints are too tightly held on the forearm this contracture complication may result. Inspection of all bandages, splints, and forced positions of flexion must be made religiously and frequently.

It is especially important, following elbow injuries and forearm fractures in childhood, that the parts (the elbow, the forearm, the hand) be looked at during the first twenty-four and forty-eight hours so as to detect any evidences of undue pressure in the apparatus used.

The dangerous initial increase of pressure may be ushered in by almost no complaint on the part of the patient other than that the splint or bandage seems a little tight. By careful and frequent inspection dangerous pressure may be avoided.

Stone mentions a case from the Children's Hospital, Boston, in which the pronator quadratus alone was the muscle affected in a contracture associated with fracture of both bones of the forearm. Permanent pronation resulted. It was relieved by operative division of the muscle.

Fig. 554.—Case I in Mr. Dudgeon's series showing characteristic deformity of Volkmann's contracture. The original injury was in December, 1896. This photograph was taken November, 1901, five years later. No treatment. Note final terrible result.

Volkmann's contracture is a most serious matter; if recognized, it can be remedied; if misunderstood, a late attempt at relief is often unavailing. It occurs far more commonly than is generally supposed. The cause of the contracture is probably an ischemic necrosis of the muscles, an ischemic myositis, dependent upon too great pressure upon the soft parts. The vascular supply is interfered with and the muscle tissue dies, leaving a cicatricial-like tissue

Fig. 555.—Volkmann's contracture following fracture of the lower third of humerus. Child twelve years old. Operation ten weeks after the accident, by tendon lengthening, restored motion after one year almost normally in elbow, forearm, wrist, and fingers, but not as strong as formerly. Arm before operation. Note: 1, Transverse scar 3 inches long running half-way round the arm 3 inches above the elbow-joint; 2, atrophy of flexor bellies; 3, flexion and fixation of wrist; 4, extension and fixation of proximal phalanges; 5, acute flexion and fixation of two distal segments of phalanges (case of Ferguson, Chicago).

in its place—an ischemic necrosis. Cases of Volkmann's contracture may occur when no splint has been used and following thrombosis of vessels.

This contracture is seen often in the arms of children who have fractured the lower end of the humerus, elbow, or forearm. The splint is applied too tightly. No allowance is made for the usual subsequent swelling. The

damage may be done in two or three days. Upon discovering the condition the fingers are dusky in color and swollen. There is rarely any pain. Upon the forearm usually will be found a slough or a pressure sore apparently extending only through the skin (see Fig. 553).

The importance of frequently inspecting the part fractured and the extremity involved is illustrated in Fig. 553. This child received an injury to the upper extremity (the details are unessential); the arm was immobilized too securely by wooden splints. Instead of there having been made regularly, at short intervals, an inspection of the arm, the splints were left on many days.

The result of pressure upon the venous circulation and the soft parts is seen in the permanent deformity present. The position of the fingers is characteristic—viz., the wrist is extended, the metacarpophalangeal joints are extended, the interphalangeal finger-joints are flexed. Upon flexing the wrist the fingers can be extended. The hand is pronated and the forearm is semiflexed. Supination and pronation of the forearm are impossible. The flexor group of muscles of the forearm is much wasted. There is a thickening of the forearm at the place corresponding to the base of the ulcer. Sensation in these cases is usually normal. The electrical reactions are normal. The hand feels cold and appears blue. The skin is smooth. The bones, in cases of long duration, are undeveloped, as in infantile paralysis.

Fig. 556.—Volkmann's contracture. Note disappearance of flexion of fingers in wrist flexion. This case was operated by Littlewood by tendon lengthening, with satisfactory functional result (case of Littlewood, Leeds).

Littlewood has emphasized the fact that a splint improperly applied is not the sole cause of the condition, for the contracture has followed where no splint has been worn. Tremendous swelling of the soft parts may cause local pressure upon the circulation, so that the etiology is well expressed thus: *The contracture is the result of prolonged interference with the normal venous circulation.*

A case of Volkmann's contracture usually gives the story of an injury to the elbow or forearm associated with a tremendous swelling of the soft parts. Splints have been applied. The paralysis and contracture appear at about the same time, synchronously. In paralysis from nerve origin contracture comes later and gradually increases.

Peripheral nerve paralysis must be differentiated from Volkmann's contracture. The history and electrical reactions will clear these up; of course, a peripheral nerve may be involved secondarily in Volkmann's contracture This fact must not be lost sight of.

Disturbances of sensation appear in certain cases of Volkmann's paralysis due to the pressure upon one or more of the nerves of the forearm, usually the ulnar, sometimes the median and radial, and, unfortunately,

Fig. 557.—Volkmann's contracture. Note flexion in wrist extension (case of Littlewood, Leeds).

sometimes all three. This pressure upon the nerve is caused by the cicatrix of the damaged part. The exact area of disturbed sensation will depend

Fig. 558.—Volkmann's contracture following an injury to the elbow and treatment by splints. Note scar in upper third of the palmar surface of the left forearm. Note attitude of left hand and fingers.

upon the precise nerve or nerves involved. Atrophy of the muscles supplied by the involved nerve will be evident.

The contracture following anterior poliomyelitis and Little's disease should be borne in mind and not confounded with Volkmann's contracture.

Treatment.—When a case of Volkmann's contracture presents itself for treatment, two questions must always be answered. Are the nerve trunks

Fig. 559.—Case I. Anteroposterior view of right elbow. Compound intercondylar T-fracture involving joint. Note that the lower end of the humerus is fractured and driven down between the fractured and separated condyles. The proximal end sustained a subcoracoid dislocation (Gilcreest).

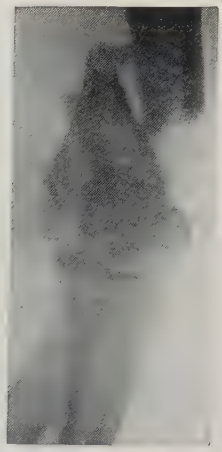


Fig. 560.—Case I. Lateral view of right elbow. Note that the two lower fragments are projecting anteriorly. Usually these fragments project posteriorly (Gilcreest).

involved in the cicatrix? Can the contractures, as such, be relieved? A freeing of the nerves will often effect great improvement. The severity of

Fig. 561.—Case I. Note how traction of pneumatic pad not only pulls down but pushes back lower fragment (Gilcreest).

Fig. 562.—Case I. Lateral view of left elbow. Note compound fracture of olecranon process into joint (Gilcreest).

the particular case and the special features present will determine the exact procedure to be employed. If a case is seen immediately after the injury (*i. e.*, within a week or two) it may be that massage and stretching of the

Fig. 563.—Case I. On account of the dislocation of the shoulder this arm was put in abduction for two weeks in a Cleary right-angle aëroplane splint with traction on forearm (Gilcreest).

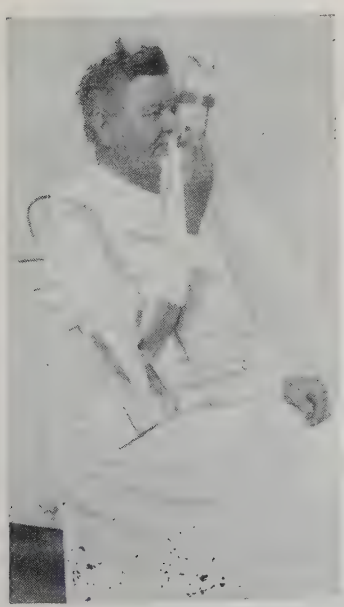


Fig. 564.—Case I. Position used at the end of two weeks. The flexion of the forearm was increased daily until an acute angle was obtained. Traction is exerted on a pneumatic pad in elbow (Gilcreest).

Fig. 565.—Case I. Note sand-bags in hand with hot applications on elbow-joint. The method used for obtaining extension after joint has been held in acute angle for some time (Gilcreest).

muscles of the forearm permanently and continuously for several months will give a satisfactory result. Cases are recorded in which this is the result

Fig. 566.

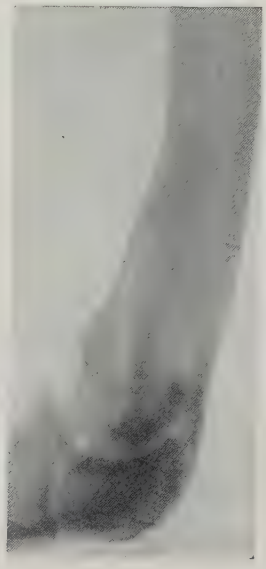


Fig. 567.

Fig. 568.

Fig. 566.—Case I. Anteroposterior view of right elbow six months after injury. Note how well the widely separated condyles have attached themselves to the humerus (Gilcreest).

Fig. 567.—Case I. Lateral view of right elbow six months after injury. Note the perfect anatomic alignment of the two condyles with the main shaft (Gilcreest).

Fig. 568.—Case I. Lateral view of left elbow six months after injury. Note that while the *x*-ray does not reveal perfect bony union, the functional result is perfect (Gilcreest).

Fig. 569.—Case I. End-result. Note that flexion of left elbow is perfect and only slight limitation of right elbow (Gilcreest).

Fig. 570.—Case I. End-result. Note extension of both elbows (Gilcreest).

(Dudgeon). The stretching is best done without an anesthetic. If done under anesthesia the stiffness is apt to become greater than before treatment. Cases that are seen within a few weeks of the appearance of the contractures

may be much benefited by placing the hand and arm in a banjo splint with continuous finger traction. Great immediate improvement results which is quite surprising at times.

If the case is seen when the contracture is established, operative measures alone will be of assistance. The contracture usually increases for two or three months before reaching its maximum. Operative treatment had better be delayed until this maximum contraction is established.

Four operative procedures are to be considered: 1. A lengthening of the flexor tendons of the forearm (Littlewood and Davidsohn, 1891). The exact amount of lengthening of the tendons is determined by the ability fully to extend the fingers with the wrist in the extended position. 2. A shortening of the radius and ulna (Garré, 1895) to compensate for the contraction of the muscles. 3. A myotomy of the muscles (Bradford, 1901) has been successfully done. 4. A dissection of the nerves (Hayward Cushing, 1904) free from the cicatrix will often restore nerve function. It may be impossible to improve the contracture by any other means than freeing the nerve and then stretching the contracted parts.

Fig. 571.—Case I. End-result. Note how patient can use the right elbow for eating and shaving (Gilcreest).

Fig. 572.—Case I. End-result. Note complete re-establishment of carrying angle (Gilcreest).

Following operative treatment it is very necessary to continue active and passive movements, massage, and faradic stimulation of muscles for many months to increase the functional usefulness commensurate with the increased range of passive motion secured by operation.

The results following operation have been pretty satisfactory. Without treatment of any kind the condition is most deplorable.

Fractures of the Lower End of Humerus Entering the Elbow-joint in Adults.—The principles underlying the treatment of these fractures in childhood and adolescence are the principles involved in the care of similar fractures in adults. For various reasons, notably the greater trauma, the more extensive separation of fragments, the tendency for adult joint lesions to

ankylosis from damaged soft tissue infiltrations, excessive callous formation and less easily controllable conditions following the injury, and the generally recognized fact that fractures into the elbow-joints of adults have given in the past relatively poor functional results, I believe that the treatment of an adult elbow-joint fracture should be very carefully thought out from the day of the injury.

Gilcreest and others have treated badly separated T or condylar fractures with almost perfect functional results by applying skilled traction, by making approximate reposition, and by early guided active motion. This non-operative method is therefore established as possible of securing good function. The difficulty is not always with the applicability of the method as with the ignorance of the surgeon in the use of the method.

In certain uncomplicated recent fractures of the condyle or condyles of the humerus I believe, if operation can be done early after the injury, the fragments should be reduced and held absolutely fixed by operation and some form of internal fixation followed by early guided active movement. Partial excision of the elbow has been followed (Hitzrot) by satisfactory results in a few cases in which it has been used. Children get good results, but adults past middle life are apt to have some limitation of motion following a fracture which enters the elbow-joint.

CHAPTER XIII

PERIPHERAL NERVE INJURIES ASSOCIATED WITH FRACTURES

Nerve injuries are found associated with fractures quite commonly. They are overlooked because of the hasty and casual examination given fracture cases. Many of the slight injuries to nerves are not noted or might be missed in an otherwise careful examination. Many of the injuries that are severe undergo spontaneous or natural recovery of the paralysis without treatment.

Classification.—The lesions of the peripheral nerves according to the time of the appearance of the nerve involvement are conveniently divided into (*a*) primary, (*b*) secondary, and (*c*) late lesions.

(*a*) A primary lesion occurs at the time of the injury to the bone. It is often overlooked at the outset. Its presence may be evident on the removal of the splint for the first time. The patient may first direct attention to it. The injury to the nerve may be a simple contusion or a complete division of the nerve trunk.

(*b*) The secondary lesion develops gradually during the healing of the fracture. It is usually due to a stretching of the nerve over growing callus or a displaced fragment of bone, a compression by bone fragments, or it may be due to an inclusion of the nerve in callus or cicatricial tissue.

(*c*) The late paralysis is peculiar in that it makes its appearance many years after the fracture occurred. It comes so long after the original injury that in some cases the accident has been entirely forgotten. It is absolutely essential that very careful examinations for nerve injury should be made whenever fracture cases are first seen. Moreover, those fracture lesions which are liable to subsequently be the cause of nerve difficulties should be so treated as to prevent subsequent neurological symptoms.

I will record here the findings of Lewis and Miller[1] in some detail. These accumulated facts summarily presented represent the literature and the experience at the Presbyterian Hospital, Chicago, a grouping of 239 cases of peripheral nerve injuries associated with fractures. These facts will serve to determine the common lesions. A knowledge of the possibilities will assist in their detection, care, and prevention. Of the 211 cases of nerve paralysis in which a record was made, 42 per cent. were secondary, 24 per cent. were primary, and 22 per cent. were late paralyses. It is very likely that many of the secondary lesions were really primary, but overlooked. Of the late paralyses, the greater majority (87.6 per cent.) were associated with fractures of the lower end of the humerus. Of the nerve injuries associated with fractures, 57.6 per cent. were of the musculospiral nerve; 25.4 per cent. were of the ulnar nerve; 5.5 per cent. were of the median nerve.

[1] Dean Lewis and E. M. Miller, Trans. Amer. Surg. Assoc., vol. xl, 1922, p. 489 E. M. Miller, Surg., Gyn., and Obst., vol. xxxviii, 1924, p. 37.

The *musculospiral* injuries are associated with fractures of the middle third of the humerus in 36 per cent. and of the lower third of the humerus in 32 per cent.

The *ulnar nerve* injury in 90 per cent. is associated with fractures of the lower third of the humerus.

The *median nerve* injuries in 75 per cent. are associated with fracture of the lower third of the humerus.

In fracture of the lower third of the humerus the surgeon must be constantly mindful of nerve lesions, either musculospiral, ulnar, or median. Of the cases of primary paralysis, 77 per cent. were of the musculospiral nerve; of the cases of secondary paralysis, 69.6 per cent. were of the musculospiral nerve; of the late paralysis, 94 per cent. were of the ulnar nerve.

It may be often difficult to differentiate between physiological interruption of the nerve current and anatomical division of the nerve by the most exact and careful neurological examination.

It is the conclusion of Lewis and Miller, with which I agree, that if recovery has not commenced within three months after the injury the nerve involved should be explored and those surgical procedures carried out demanded by the findings in the case. It may be found that a neurolysis will most often be required.

A resection of the humerus should not be done for end-to-end suture of the musculospiral nerve.

The Musculospiral Nerve in Fracture of the Humerus[1]

Injury to the musculospiral nerve is a serious accident and demands careful consideration. It is a lesion that is overlooked and is often discovered unexpectedly. Musculospiral paralysis is an infrequent complication of fracture of the humerus and occurs chiefly in fractures of the middle third of the bone; a little less frequently it occurs in fracture of the lower third, and, rarest of all, it occurs in fracture of the upper third of the humerus. Musculospiral paralysis occurs in from 4 to 8 per cent. of the cases of fracture of the humerus.

It is possible to have a musculospiral paralysis in a case of fracture of the humerus from causes entirely independent of the fracture.

Moreover, the fracture of the humerus is not the only bone fracture which may damage the musculospiral nerve; ulnar fracture in the upper third has been attended with symptoms pointing to involvement of the posterior interosseous nerve.

Anatomical Facts.—The musculospiral nerve pursues its course through the upper arm in close relation to a solid structure—the humerus—and maintains its closest relation with the bone and periosteum in its middle third (Fig. 573). This portion of the nerve is not embedded in soft tissues. Moreover, its course is spiral, thus subjecting itself peculiarly to traumata resulting from displacement of fragments.

[1] See paper by Scudder and Paul, Annals of Surgery, December, 1909.

Before the nerve enters the groove or just about at that point it gives off three cutaneous branches which are described as supplying the upper arm; these branches run more in the muscle tissue and preserve their function in the large majority of traumatic paralyses of the musculospiral.

Primary and Secondary Paralysis.—Cases of musculospiral paralysis associated with fracture of the humerus are divided into two broad divi-

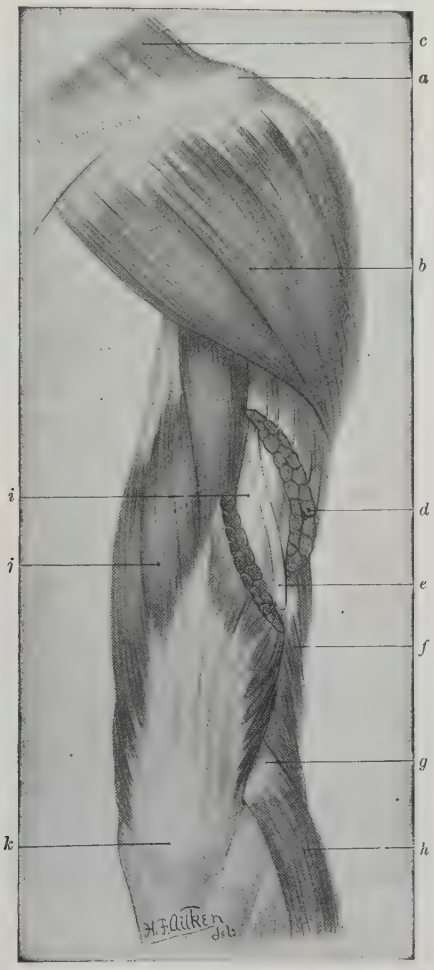


Fig. 573.—Relations of musculospiral nerve on outer side of arm (from dissected specimen): *a*, Acromion; *b*, deltoid; *c*, trapezius; *d*, triceps; *e*, musculospiral nerve; *f*, brachials anticus; *g*, *h*, extensor group; *i*, humerus; *j*, triceps; *k*, olecranon.

sions (Riethus) based on the time when symptoms of nerve involvement appear. Thus they are: (1) immediate or primary, and (2) secondary.

A further subdivision of the primary cases is made into: (*a*) the nerve is damaged by the injury, (*b*) the nerve is damaged by the bone (Goldstein).

The symptoms of nerve impairment appear immediately in the primary cases and stress is laid on the importance of examining every fractured

Fig. 574.—Double fracture of humeral shaft. Immediate musculospiral paralysis. Union of bones in six weeks. Operation to free nerve from lower fragment. Sensation and motion returned. Same case as Fig. 576.

Fig. 575.—Appearances of musculospiral paralysis following fracture above the condyles of the humerus. Note the wrist-drop in completely relaxed position of wrist (after Pedro Chutro, Buenos Aires).

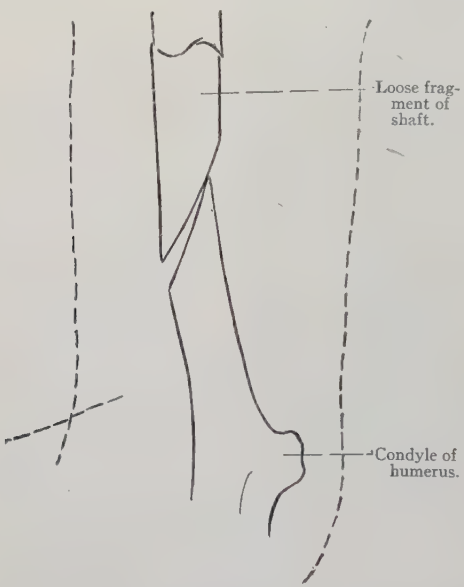


Fig. 576.—Same as Fig. 577. Lateral view to show displacement of fragment (*x*-ray tracing).

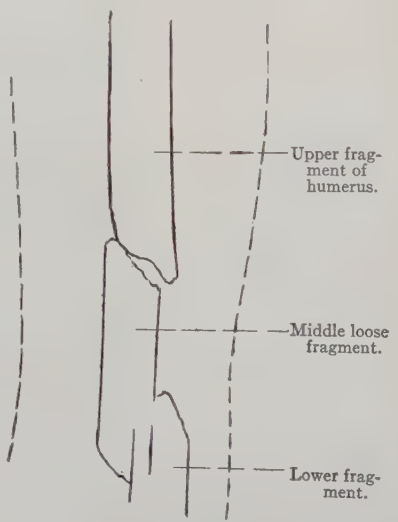


Fig. 577.—Double fracture of the humerus. Paralysis of the musculospiral nerve. Immediate union of bone. Suture of nerve found caught between fragments. Gradual recovery. Same as Fig. 576 (*x*-ray tracing).

humerus with reference to neural integrity. Many times after the recognition of paralysis of the musculospiral nerve uncertainty of its duration has had to be admitted by the attending surgeon.

The secondary cases are those in which musculospiral paralysis develops from nerve compression or stretching during the course of osseous repair. The secondary cases are further divided (Fessler) into (*a*) those occurring during the primary fracture healing process, and (*b*) those subsequent to fracture healing. In the latter variety necrosed bone, a pseudo-arthritis, or a fistulous tract may be the cause.

Fig. 578.—One year after suture of musculospiral nerve. Note relaxed position of hand. (Massachusetts General Hospital Clinic.)

Musculospiral nerve injury may complicate fracture of the humerus at any age, and has been known to occur with obstetric fracture; infants and adolescents present numerous examples of paralysis.

Fig. 579.—One year after suture of the musculospiral nerve. Note powerful extension of wrist. (Case of H. H. A. Beach, Massachusetts General Hospital Clinic.)

Etiology.—The principal factor in the etiology is the anatomical relation of the musculospiral nerve to the humerus, especially in the middle third of the bone.

In the *primary* cases coincident with or immediately following the fracture the nerve may be contused, stretched, divided partially or completely, pinched between the fractured ends, or be impaled by a splinter.

The *secondary* cases are comprised largely in one class, namely, callous inclusion of the musculospiral nerve, which by pressure, as is generally

assumed, impairs the function of the nerve till even total paralysis is developed; or if the callus gives a free tunnel for the nerve it undergoes stretching to a degree that suspends more or less completely its functions. Even if the nerve is not included in the callous tissue, but is pushed before it, the course of the nerve over the rounded mass may result in a stretching with loss of function.

Symptoms.—The symptoms of musculospiral involvement at the time of fracture or during repair are largely those of motor impairment or complete motor loss. The forearm extensor muscles controlling the wrists and digits lose either partially or completely their power; and some degree of anesthesia may be established in the radial nerve supply. The sensory loss is found chiefly on the dorsum of the hand between the metacarpal bones of the thumb and forefinger, the so-called "punctum maximum" of anesthesia.

Fig. 580.—Note the situation of cicatrix locating lacerated wound of upper arm which damaged musculospira nerve. (Massachusetts General Hospital Clinic.)

In general, the sensory symptoms have no relation to the degree of motor loss. It is said (Fessler) that sensory disturbance follows primary paralysis only and that secondary paralysis has no sensory disturbance.

The symptoms are largely motor; the paralyzed muscles are: extensor ossis metacarpi pollicis, extensor communis digitorum, extensor carpi radialis, extensor carpi ulnaris, extensor longus pollicis, extensor brevis pollicis, extensor indicis, extensor minimi digiti, and supinator longus and brevis.

The position assumed by the arm and hand in musculospiral paralysis is flexion of the fingers at the metacarpophalangeal joints with ulnar abduction and flexion of the wrist; the latter is extreme if division of the nerve exists and is only partial if continuity of the nerve is preserved; the thumb is adducted and the forearm pronated (see Figs. 574, 575).

In primary paralysis or paresis the onset is as sudden as the break of the bone. The secondary cases may develop insidiously along with the compression, with formications and sharp pains along the nerve and functional failure by degrees.

No definite time can be set when the callus interferes with nerve function, but in a general way it is in the second week or later. It is important to ascertain whether a period of preservation of function of the nerve immediately follows the fracture. The motor and sensory disturbances set in practically simultaneously in secondary cases (Riethus).

Trophic disturbances other than muscle wasting are rare, but may occur, and in exceptional cases the nails, skin, and cellular tissue may show nutritional deterioration.

Callous incarceration of the musculospiral with total paralysis may be attended with neuralgic pain, especially on movement.

From callous irritation the perineurium may proliferate in a spindle-like thickening, forming a sort of neuroma. On the other hand, the nerve may be flattened and thinned.

Prognosis.—The prognosis in a general way is favorable to recovery in the large majority of cases which have had the benefit of operative procedure. According to Bruns, 50 per cent. of all cases require operation.

Some cases have been operated on a second and a third time. There exist records of cases operated on sixteen months and three and a half years after fracture, with restoration of nerve function. In general, the longer the duration of paralysis, the less favorable the prognosis.

The time of improvement after operation varies from a few weeks or even days to months; generally it begins in three to four months and final cure is completed in about a year's time. One case (Riethus), with resection of the humerus, recovered in two years, improvement setting in first after one year.

Cases are recorded of quick return of sensation in one day, in two days, and eight to ten days after operation. The general law seems to hold true for the musculospiral, that sensation returns before motion after paralysis of both.

Electric reactions in some measure are of prognostic aid, but their value is limited because they cannot indicate the pathological condition. A complete reaction of degeneration is more unfavorable than a partial one, and though it would make the prognosis grave, is by no means a contraindication to operation. But a change in the character of the reaction of degeneration is perhaps of most significance, being unfavorable when the negative current response of the muscle is less than the positive. Most favorable is the presence of faradic response in the nerve, which, however, is usually subsequent to evidence of voluntary return.

Indications for Operation.—What are the indications for operation in musculospiral paralysis complicating fracture of the humerus and its healing? Every case of paralysis, whether primary or secondary, requires careful study as to the question of operation. The pathological condition of the

nerve is the vital point, and, unfortunately, similar symptoms may attend a varied pathological condition; there is not even a pathognomonic symptom of complete division of the nerve.

Of more importance than the fact of some failure of function in the musculospiral is the time this loss of function has persisted and whether it is getting less or increasing. Many cases have recovered without operation. Many other cases are reported in which exploration was unnecessary; if primary paresis persists and increases, then operate. If four to six months pass without improvement, operation should be resorted to. Secondary paralyses never recover spontaneously, so that operation is always indicated in this class of case. Moreover, it should be done early, though late interference has proved beneficial. A case of primary paralysis should not be operated if the symptoms are not increasing.

Fig. 581.—Note ununited humerus twelve years after injury. Muscles seen in powerful contraction. When muscles are at rest the arm hangs straight at the side. Wrist-drop is still present. (Massachusetts General Hospital Clinic.)

The *Roentgen ray* has been of service. First of all, it demonstrates the position of the bones. Good alignment would assure the surgeon that the nerve was not on a stretch continuously. A large shadow of callus would be of corroborative value in secondary cases. The information as to the nerve is indirect, for, after all, we have to infer what may have happened to the nerve from what is found as to the condition and position of the bone.

The results of *electrical findings* are of some aid in demonstrating the degree of paralysis present, and may be of the greatest help in determining functional restoration or impairment. But the pathological condition and the pathological future of the nerve are the essentials to be determined as nearly as possible; and the knowledge of the electrical reactions helps only a little. A contusion cannot be distinguished by the electrical reaction from damage due to callus or even a complete division of the nerve.

In the treatment of these cases the question of operation requires conservative consideration. If a given case is going to get well with treatment other than resection, suture, or operative release of the nerve, operative interference is not required. On the other hand, if permanent paralysis of the extensors is inevitable, an operative procedure is demanded. But such definite knowledge is not attainable in every case. In the consideration of individual cases we should approximate as nearly as possible this ideal attitude before rendering an opinion as to operation.

A careful operation, even if unnecessary, would not interfere materially with ultimate recovery, while an error in failing to operate would be most regrettable. So it seems advisable, on the whole, to favor surgical investigation in cases in which doubt exists.

The time of operation is to be chosen at as early a date after symptoms of paralysis appear as possible. The later degenerative changes in both

Fig. 582.—Note left wrist-drop sixteen years after accident. Note atrophy of forearm and hand muscles. (Massachusetts General Hospital Clinic.)

nerve and muscle are thus reduced to a minimum, and in the progress of a partial but increasing paralysis may be arrested.

Indications for or against operative procedure turn on the pathological diagnosis. The more severe the trauma, the greater the probability of some tearing through the nerve or even complete division, especially if there has been much rotation of the peripheral fragment, or it has been for a moment pulled apart from the proximal fragment, or the two fragments have been displaced out of line or at an angle; and in such a position the nerve on the stretch may be worn through by an edge of bone. Such conditions, as well as that of being caught between the fractured surfaces and transfixion by a splinter of bone, are among the rarer complications pathologically; but if they exist, operation is imperatively required at an early stage. The description of an illustrative case follows:

Eight cases of the 11 have no wrist-drop at present. Three cases showed no improvement in the nerve function following operative interference.

Of these 3 cases, 1 died three years following suture of the nerve, showing no improvement in the nerve function; another has had three unsuccessful operations for ununited fracture of the humerus at intervals of six to eight years; the third case had at the first operation the nerve freed, resected, and sutured, and at the second operation the bone shortened by resection, the nerve, found bulbous, resected and sutured. After sixteen years there is no return of function in the nerve.

Eight of these cases were badly injured. The trauma was very severe; the arm was caught in the shaft or the belt of an engine, or had received a gunshot wound, or was crushed by machinery. Most all the cases were operated upon some three or four months following the accident. The longest interval between accident and operation was three years. This case recovered functional usefulness and the musculospiral supply. Improvement in these cases was first noted six months to one year following the operation.

CASES OF MUSCULOSPIRAL PARALYSIS, MASSACHUSETTS GENERAL HOSPITAL CLINIC

(Tabulated according to time elapsed.)

No.	Date of accident.	Date of operation.	Interval between accident and operation.	Result and date of last observation.	Interval between operation and final observation.
1	May 1, 1901....	Sept. 21, 1901.....	4½ months.	Sept., 1902. No wrist-drop. Improving.....	1 year.
2	Dec. 16, 1896...	May 22, 1897.....	5 months.	Dec., 1906. Excellent result.....	9 years.
3	Jan., 1903.....	April 7, 1903.....	3 months.	March, 1908. Perfect result.....	5 years.
4	Oct. 11, 1905....	Jan. 18, 1906.....	3 months.	Jan., 1907. Perfect result.....	1 year.
5	Aug. 5, 1897....	(1) July, 1900..... (2) August, 1900. (3) July, 1901.	3 years.	1907. Good functional result. Movements about half normal..	7 years.
6	April, 1900.....	July, 1900.....	3 months.	Oct., 1903. No improvement....	3 years.
7	July, 1893.....	(1) Dec., 1893, bone.. (2) Feb., 1895, nerve. (3) Feb., 1899, bone. (4) Feb., 1907, bone..	1 year, 7 months.	Feb., 1907. Marked wrist-drop..	12 years.
8	Nov. 17, 1905...	Dec. 16, 1905.....	3 weeks.	Dec., 1906. Perfect functional result.....	1 year.
9	Oct., 1890.....	Feb. 21, 1891.....	4 months.	April, 1907. Wrist-drop complete.	16 years.
10	Nov., 1899.....	June, 1900.....	7 months.	Dec., 1906. Fair result; Extension of wrist possible.....	16 years.
11	March 2, 1899...	April 27, 1899.....	3 weeks.	Nov. 22, 1900. Perfect result, except extension of thumb.....	1 year, 7 months.

Facts of Importance Concerning Musculospiral Paralysis.—Of the nerve injuries associated with fractures 57.6 per cent. are of the musculospiral nerve (Lewis-Miller).

Fracture of the middle third of the humerus is the fracture most commonly complicated by musculospiral paralysis (36 per cent. of the cases);

32 per cent. of the musculospiral injuries are associated with fractures of the lower third of the humerus.

Fracture of the humerus at any age may be associated with musculospiral paralysis.

Musculospiral paralysis is primary if it dates from the accident, and it is secondary if it is subsequent to the accident.

Primary paralysis of the musculospiral nerve indicates a more severe injury to the nerve than does secondary paralysis.

The diagnosis of the exact pathologic condition of the musculospiral nerve following trauma to it is of the greatest importance and is difficult to determine.

Progressive impairment of function or stationary paralysis of the musculospiral nerve complicating fracture of the humerus justifies and may demand operation.

Operation means the release of the nerve from compression or tension and often resection and suture, and always guarding against recurrent compression or stretching.

End-to-end suture is the sound operative procedure for divided musculospiral and other peripheral nerves.

A late suture (months after the injury) is attended by technical operative difficulties not present in an early suture (soon after the injury).

Resection of the humerus to allow of approximation of the divided ends of the musculospiral nerve is not a good procedure if it can be avoided.

Electric reactions cannot determine the pathologic condition. They are of value in determining the course of events.

The prognosis after operation is good; the earlier a necessary operation is done, the speedier the cure.

Exercise of paralyzed muscles by electric stimulation (galvanism) is helpful.

Sensory symptoms are variable; in general, the sensory symptoms have no relation to the degree of motor loss.

LATE ULNAR NERVE PARALYSIS

A cobbler about forty years of age complained of wasting of the muscles of his right hand so that he had difficulty in using his hammer in mending shoes. Many years before he had broken his elbow, but aside from a deformity at his elbow it never gave him any trouble until six months before coming to the surgeon, within which time a complete ulnar nerve paralysis had developed. The above case Miller[1] cites from the experience of Panas in 1878 as the first recorded instance of late ulnar nerve paralysis.

The following facts fill up the picture of late ulnar involvement after fracture:

The primary cause in practically all cases of late ulnar paralysis is a fracture at the elbow in childhood (three to five years).

[1] Edwin M. Miller, Surg., Gyn., and Obst., vol. 38, 1924, p. 37.

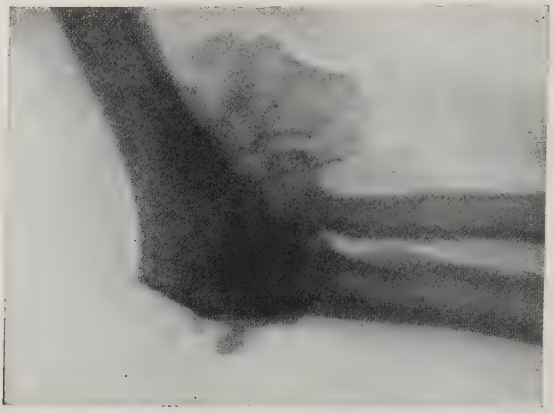


Fig. 584.—Case I. Ununited fracture of the external condyle in childhood. Cubitus valgus. Ulnar nerve palsy beginning twenty-two years after the injury (Miller).

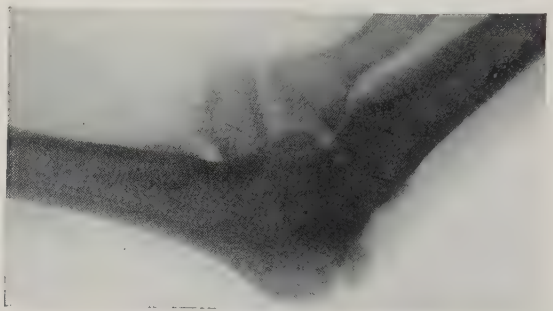


Fig. 585.—Case II. Ununited fracture of the external condyle in childhood, with growth disturbance resulting in marked cubitus valgus and complete ulnar nerve palsy (Miller).

Fig. 586.—Case III. Ununited fracture of the external condyle in childhood with resultant cubitus valgus. Ulnar nerve palsy beginning thirty-six years after the injury (Miller).

Fig. 587.—Case IV. Compound fracture involving the external condyle of the humerus in boyhood, resulting in a gunstock deformity at the elbow. Onset of the ulnar palsy twenty-three years after the injury (Miller).

Although occasionally the site of the injury may be at the internal condyle or in the supracondylar region, in the vast majority of cases the line of fracture begins laterally just below the epicondyle and passes obliquely downward and inward into the joint, causing complete separation of the external condyle (capitellum)—Mouchet's conception.

The broken capitellum is displaced laterally and forward, and the fractured surface is twisted outward, is not accurately reduced by manipulation, and as a result non-union of the condyle occurs. The growth of the humerus on its lateral side is then interfered with to such an extent that a cubitus valgus gradually develops.

Mechanism of Pressure Paralysis.—As the deformity increases the olecranon process becomes impinged against the medial condyle, the ulnar groove becomes but a shallow depression, and the nerve itself displaced from its

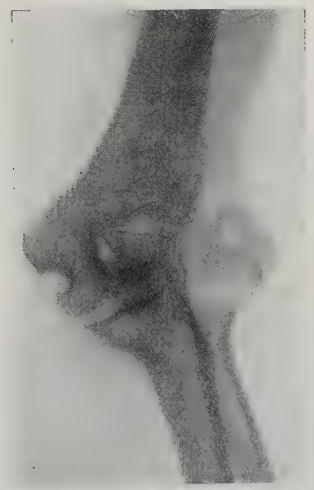


Fig. 588.—Case V. Old ununited fracture of the external condyle of the humerus in childhood, with development of cubitus valgus and ulnar nerve palsy beginning eighteen years after the injury (Miller).

Fig. 589.—Case VII. Ununited fracture of the external condyle at the age of four years. Cubitus valgus. First signs of ulnar nerve palsy beginning fifteen years after the injury (Miller, Surg., Gyn., and Obst., January, 1924).

bed, where it becomes subjected not only to stretching when the arm is flexed, but to repeated trauma, which in time leads to partial or complete ulnar paralysis (see Fig. 590).

Time of Appearance of Paralysis.—This paralysis may begin as early as three years or as late as forty years after the injury, but in the majority (40 per cent.) of cases it is noticed between the twentieth and thirtieth year after the fracture occurs; 19 per cent. of the cases studied by Miller and Lewis were noticed between the tenth and twentieth years; 15 per cent. were first noticed between thirty and forty years after the accident. Further it was learned from the collected cases that 47 per cent. of the late ulnar paralyses were associated with fractures of the external condyle of the humerus; 53 per cent. of these late ulnar paralyses were associated with a definite and marked cubitus valgus (Lewis and Miller).

Treatment of Late Ulnar Paralysis.—The paralysis having appeared, the treatment which has been employed in numerous instances may be grouped:

1. Correction of the deformity at the elbow by a cuneiform osteotomy of the humerus, no operation on the nerve itself being necessary. This was the operation done and advocated by Mouchet.[1]

2. Simple liberation of the nerve from its bed (Potherat, 1897). This operation is inadequate.

3. Liberation of the nerve at the elbow and replacing it in a new groove made by removal of a wedge-shaped piece of bone and lining it with an aponeurotic-fascial flap (Broca 1899, Sherren 1908).

4. Transplantation of the nerve to the flexor side of the elbow (1898). Friction and tension are eliminated.

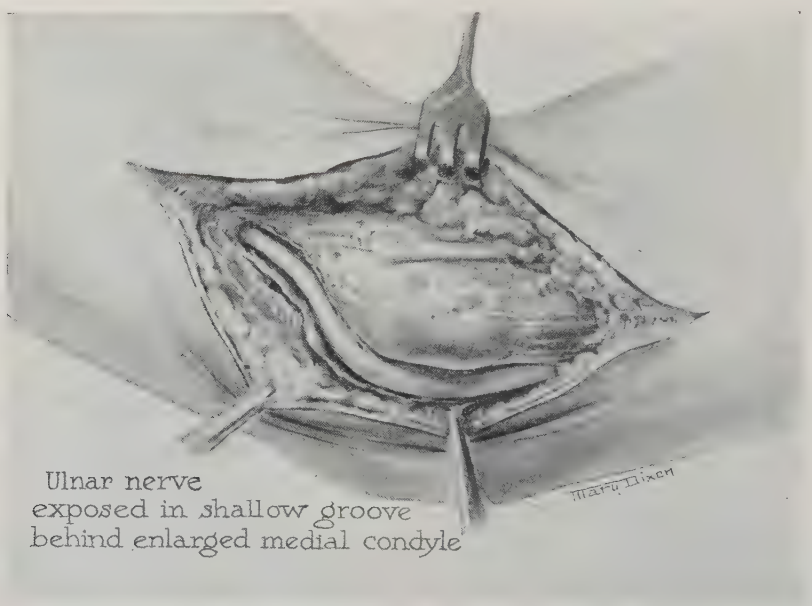


Fig. 590.—Note displaced ulnar nerve (Miller).

Miller justly thinks that deepening the ulnar groove is open to the objection that regeneration of bone may fill the deepened groove and that the nerve may become easily involved in scar tissue.

Miller advocates the method of treatment by which the nerve is transplanted to the flexor side of the condyle. Miller cites his own cases, with remarkably uniform and good results.

Operative Treatment.—Miller's method of operating is well shown in Figs. 590–592. In studying the details of the results of fracture or separation of the external condyle, particularly slight variations in growth from that epiphysis, one is impressed by the importance of accurate adjustment of the epiphyseal detachments at the external condyle. Variations from the normal may be followed in subsequent years by ulnar paralysis.

[1] Albert Mouchet, Thèse de doct., Paris, December, 1898.

Fig. 591.—Note enlarged condyle (Miller).

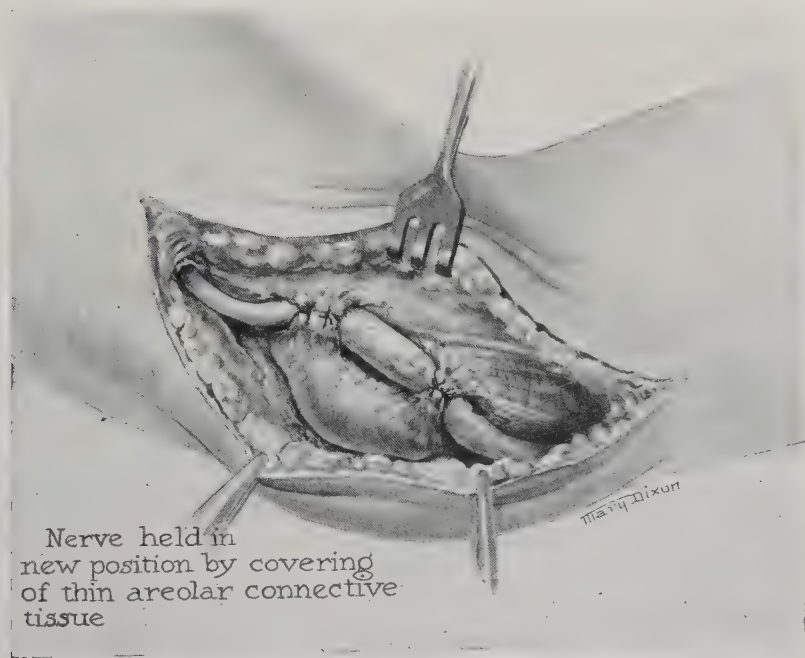


Fig. 592.—Note subcutaneous covering for nerve after its transfer (Miller).

Miller justly maintains, and I should like to emphasize his contention, that while it is true that the percentage of late ulnar paralysis is very small

in proportion to the frequency of external condyle fractures, it is quite probable that the valgus deformity is much more common than we would think, and also that if these cases could be traced long enough it would be found that involvement of the ulnar nerve occurs more frequently than the published reports indicate.

In view of these late disabling nerve involvements, and despite the compensating changes which do at times occur in bone growth following permanently misplaced epiphyses, it seems that Miller's attitude is sound, namely, in cases of injury with displacement of the epiphyses of the elbow, especially in cases of external condylar injury (capitellum), it is better to operate directly and at once to reduce and maintain reduction as accurately as possible.

Each case must be studied in detail and a decision as to treatment reached based on the merits of the specific case and accumulating experience.

The surgeon is urged to consider these external condylar injuries in childhood as potentially very serious. He is urged to treat these cases not only from the point of view of the immediate result, but from the point of view of the possible remote result in years to come—the immediate surgery may be preventive surgery.

Early Involvement of the Ulnar Nerve.—In a series of 329 fractures early involvement of the ulnar nerve is an infrequent complication of the fracture of the lower end of the humerus, for it occurred but nine times, about 3.7 per cent. (Platt). Its injury is associated with fracture separation of the *internal* condyle.

A summary of Platt's paper:[1] The nerve lesion is usually a primary contusion—a physiological block without loss of continuity. The symptoms are slight, and rapid spontaneous recovery tends to occur. In exceptional cases the primary neuritis may increase in severity during the early treatment and the lesion may pass etiologically into the secondary class. A secondary ulnar neuritis may be thus an unavoidable sequel. In such cases a friction or tension neuritis is produced as a result of a disturbance of the normal relation between the nerve and its bed.

A secondary ulnar neuritis may be induced also by injudicious treatment, *i. e.*, the use of forced passive movements of the elbow in the first few weeks after the injury. Under similar circumstances a secondary neuritis may arise *de novo*.

[1] Traumatic Neuritis of Ulnar Nerve, Harry Platt, Manchester, The British Journal of Surgery, vol. xiii, No. 51, p. 409, January, 1926.

CHAPTER XIV

FRACTURES OF THE BONES OF THE FOREARM

Radius and ulna—Head and neck of radius—Chauffeur's fracture—Fractures of radius above pronator radii teres—Fractures of radius below pronator radii teres—Magnuson's suspension—Whipple and St. John "sugar tong" splint—Both radius and ulna—Plaster-of-Paris splint—Anterior and posterior wooden splints—Fracture of the olecranon—Colles' fracture.

FRACTURES OF BOTH RADIUS AND ULNA

Fractures of the forearm probably offer more problems in mechanics than any other fractures in the body, not excepting the femur. There are here two bones which form a pedestal, supporting the hand and having attached to them an intricate system of muscles which control the hand. The arm in itself is of comparatively little use; it is the fact that it controls the motion of the hand that makes it important. The ulna can be considered an extension of the arm downward and the radius an extension of the hand upward, as the ulna articulates with the humerus in a pure hinge joint and is supported by the humerus, tapering down to a smaller diameter at its distal portion than at its base at the elbow. The radius, however, is wider at its distal portion, tapering toward the elbow. The radius is concerned with motions of the hand; the ulna, with motions of the arm. The radius forms an important part of the wrist-joint, and the ulna a very small part. The ulna forms a very large part of the elbow-joint, and the radius a very small part. These two bones, of course, are joined by the interosseous membrane, the fibers of which run from the ulna to the radius in a slightly upward direction, so that a blow transmitted from the hand to the radius, driving the radius upward, has a direct pull on the ulna also, and, if the bones are fractured, has a tendency to draw the fractured fragments together. Many of the muscles of the forearm have more than one direction of pull, depending on what position the hand occupies. The pronators and supinators have in some cases almost a direct transverse pull on both bones, and, in addition to their rotating action, some of them, as the pronator radii teres, biceps, and brachioradialis, have a flexor action (Magnuson).

Sites of Fracture.—The most common sites of fracture are in either the middle or lower thirds of the bones. The fracture of the radius is often a little higher than the fracture of the ulna. It is an interesting observation (Troell) that studying a large series of forearm fractures it is noted that in individuals with incomplete ossification the fracture is usually transverse of the diaphysis of both bones of the forearm (see Figs. 602, 637, 659). If the fracture occurs in an individual with complete ossification (that is, past twenty years) there occurs a fracture of the region of the lower radial epiphysis with or without injury to the ulnar styloid process.

Symptoms.—The arm cannot be used without pain. In a muscular or fat arm with little separation of the fragments there may be no deformity excepting the localized swelling at the seat of fracture. Deformity will be determined by the displacement of the bones. If the seat of fracture is not obvious the forearm should be grasped by the two hands (see Fig. 610) and gentle but firm movement attempted, to determine the presence of abnormal motion and crepitus. Motion should be attempted in all directions, for the bones may be fractured and yet be locked when movement is made in one direction only. An *x*-ray examination is always necessary.

Incomplete or Greenstick Fracture of the Bones of the Forearm (see Figs. 613–616).—This is a partial break across the bone, with bending at the seat of fracture. In children between the ages of two and fourteen years injury to the bones of the forearm results usually in a greenstick fracture. Either one or both bones may be broken. One bone may be completely fractured, while the other is incompletely broken.

Deformity is very evident. Pain and tenderness at the seat of fracture are present. Crepitus is absent unless one bone is completely fractured. Children having these fractures are often seen a week or two after the injury; they are said to have "sprained the arm" and "are unable to use it well at the present time." Careful inspection will detect the characteristic bowing at the seat of a greenstick fracture. Slight callus will be present if a little time has elapsed since the injury.

Fracture of the Head and Neck of the Radius.—This fracture of the upper end of the radius is being discovered more frequently than hitherto because of the employment of the *x*-ray in doubtful injuries to the elbow. The fracture line is faint. The fracture is obscure. The fragments may not be separated. It is little recognized. Upon its recognition and proper treatment depend possibly the integrity of the elbow and wrist movements of pronation and supination.

The *fracture of the head* (including cases in which the fracture line involves the radio-ulnar joint capsule). These will be complete or incomplete fractures. The *complete* fractures will include marginal, comminuted and extending into the neck, and displacements of the epiphysis. The *incomplete fractures* will be the fissures of the head.

The *fractures of the neck* will be inclusive of those below the head and above the bicipital tubercle. These fractures of the neck may be complete or incomplete.

The important factor in all these fractures, aside from the displacements existing, is the degree that the orbicular ligament is torn. Apparently the extent of the laceration of this ligament, together with the unreduced displacement of fragments, determine very largely the amount of subsequent disability.

When the fracture is confined to the head of the radius and upper part of the neck it is wholly intracapsular, that is, within the orbicular ligament. The fragment is often wedge shaped. The fracture is longitudinal in direction, splitting the edges of the button-like head (Figs. 593, 595). A broken off marginal fragment may be forced through the capsular ligament or pushed

into the elbow-joint. It may become a loose body in the joint, blocking motion. A fragment is rarely completely detached from the capsule. It is, however, possible for a fragment to become partially or wholly separated

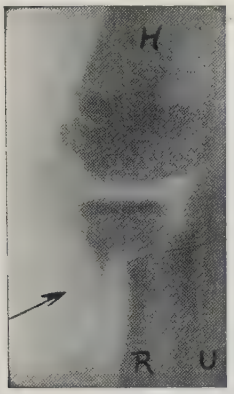


Fig. 593.—Fracture of the neck of the radius. Anteroposterior view. The arrow points to the line of the fracture.

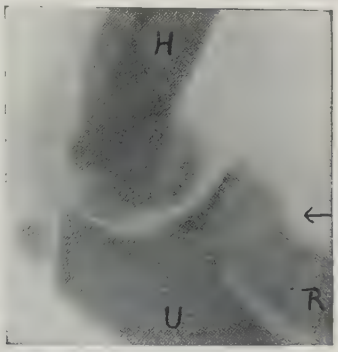


Fig. 594.—Fracture of the neck of the radius. Same as Fig. 593. Lateral view. The arrow points to the line of the fracture.

and to lie so as to check flexion of the forearm or so as to hinder pronation and supination.

Etiology.—A fall forward upon the outstretched pronated hand with elbow extended is the usual cause of this fracture of the upper end of the radius.

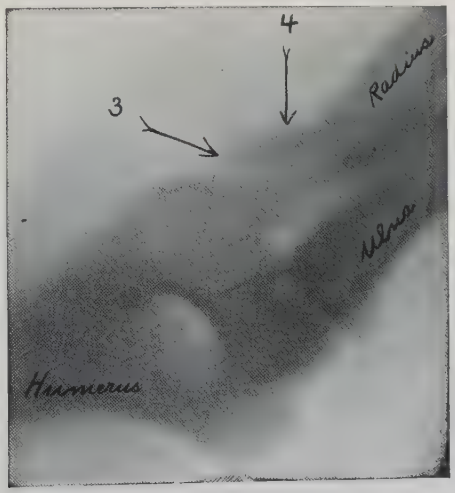


Fig. 595.—Fracture of the head of the radius in an adult. Note the longitudinal lines of fracture and the head split into three wedge-shaped pieces. Arrow No. 3 points to lines of fracture. Arrow No. 4 points to anteriorly displaced fragment. See also Fig. 596. (Porter.)

Forty per cent. of Cutler's[1] series received a fracture from a fall on the elbow directly, 20 per cent. from indirect violence.

Why the head in one case and the neck of the radius in another case is

[1] Annals of Surgery, January, 1926.

fractured is probably due to the varying amount and direction of the force acting through the shaft of the radius.

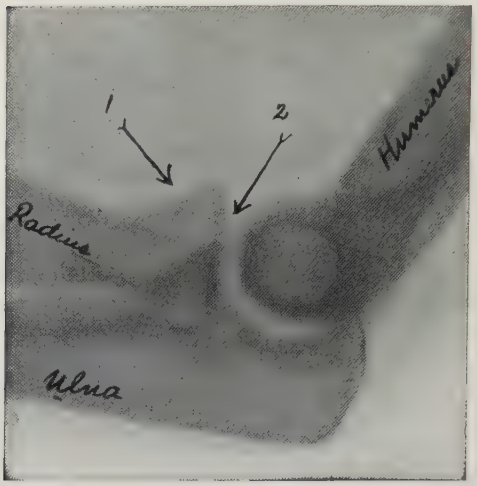


Fig. 596.—Fracture of the head of the radius in an adult. Note the longitudinal characteristic splitting of the head at Arrow No. 2. Note the fragment displaced forward at Arrow No. 1. Recovery with flexion and extension limited (Porter).

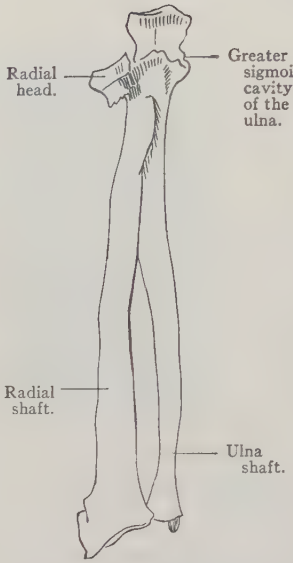


Fig. 597.—Common displacementi n fracture of the neck of the radius. This type requires operation (after Mouchet).

Diagnosis.—The fracture of the upper end of the radius is often associated with other minor or major injuries. At times it is associated with fractures of the external condyle of the humerus, with dislocation of the

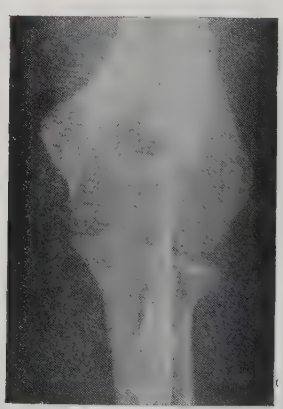


Fig. 598.—Roentgenogram. Anteroposterior view of elbow. Note fracture of the neck of the radius with change in relations of the articular surface of radius to the capitellum. Fracture of tip of olecranon (Arial George).

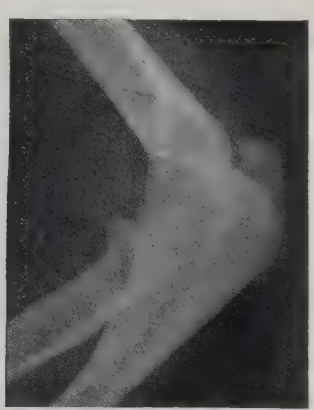


Fig. 599.—Roentgenogram. Lateral view of elbow. Note slight impaction of neck of radius and fracture of tip of olecranon (Arial George).

forearm backward, with fracture of the coronoid process of the ulna, fracture of the shaft of the ulna with dislocation of the radius alone, with subluxation of the radial head. If any of these lesions are present a fracture of the head

or neck of the radius should be looked for very carefully, although in the presence of severe injury to the elbow region the radial fracture may seem to be of secondary importance. If the neck is fractured the head may not rotate with the shaft of the bone.

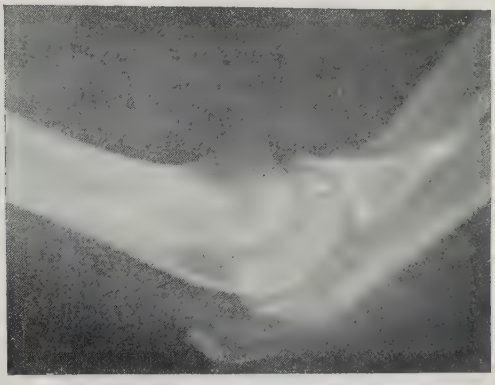


Fig. 600.—Roentgenogram of injured elbow showing a fracture of the olecranon process at its tip, elbow-joint not opened. Impacted fracture of the neck of the radius close to the head (Holmes).

Fracture of the neck of the radius occurs more often in youth and childhood, while fracture of the head occurs in adult life.

If after a fall upon the hand there is pain and swelling at the outer side of the elbow and exquisite tenderness upon pressure over the region of the

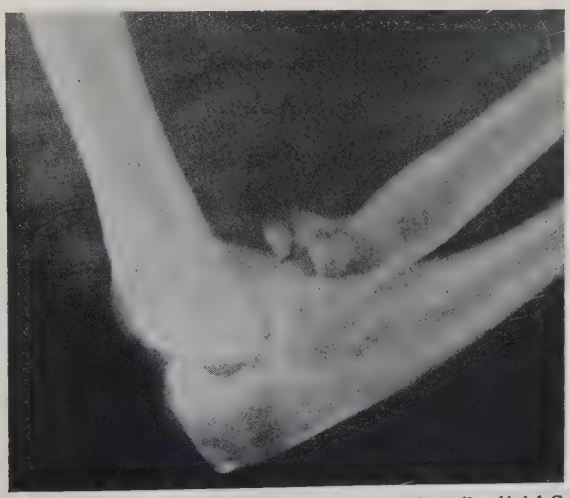


Fig. 601.—Comminuted fracture of the orbicular head of the radius (Arial George).

head and neck of the radius, and the movements of complete extension and flexion are limited and painful, together with limitation and pain in the movements of pronation and supination especially, and if other injuries enumerated above can be excluded, the diagnosis may be made of an injury to the head or neck of the radius.

The swelling over the head of the radius will not be commensurate with the pain and often great impairment of function occasioned by a fracture of the radial neck or head. If crepitus can be elicited the diagnosis is

Fig. 602.—Fracture of both bones of the forearm above wrist. A not uncommonly overlooked and frequent injury (Children's Hospital, P. Brown).

confirmed. Many physical conditions may prevent crepitus even in the presence of a fracture. If the fracture is overlooked and treated as a contusion or a sprain there may be subsequent non-union or limitation of joint

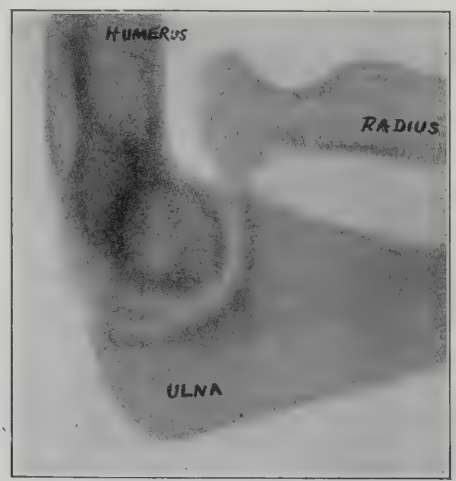


Fig. 603.—Fracture of head of radius with anterior luxation of the radius. Lateral view (Thomas).

motion; this latter is dependent upon excessive callous formation and adhesions. Persistent impairment of the motions dependent upon the integrity of the radiohumeral and radio-ulnar articulation will be the best evidence of injury to the radial head or neck.

Prognosis.—The superior radio-ulnar articulation and the upper surface of the cup-shaped head being involved in this variety of fracture, limitation in pronation and supination and in flexion and extension of the fore-

Fig. 604.—Fracture of head with postluxation of elbow (Thomas).

arm is a probable result. Neglected cases of radial head fracture may result in elbow-joint ankylosis.

Under proper treatment an uncomplicated fracture of the head or neck of the radius should result in union of fragments and normal function of the part. Adult operative cases give good results.

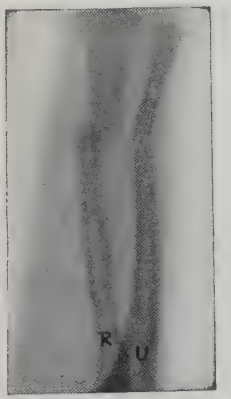


Fig. 605.—Fracture of both radius and ulna in lower third. Note tendency of lower fragments to come together and of upper fragments to separate.

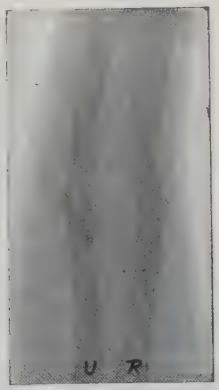


Fig. 606.—Fracture of both radius and ulna. Note tendency for all fragments to separate and bend outward away from midline of forearm.

Treatment.—In *children* and youth the elbow should be placed in the acutely flexed position with forearm in complete supination after manipulative pressure and traction on forearm. Usually after ten days guarded painless motion may be begun and along with massage will succeed in securing almost perfect function of the joint.

In *adults*, excepting in linear fractures without much if any displacement, a complete removal of the head of the radius immediately after the injury should be done. All fragments should be carefully removed. Avoid injury to

Fig. 607.—Separation of lower radial epiphysis. Note the dorsal displace ent and deformity seen in outline and that there is little lateral displacement (M. G. H., Dodd).

the joint capsule and synovial membrane. Keep the annular ligament intact. Close the wound tight. In about a week or less begin active guarded movements.

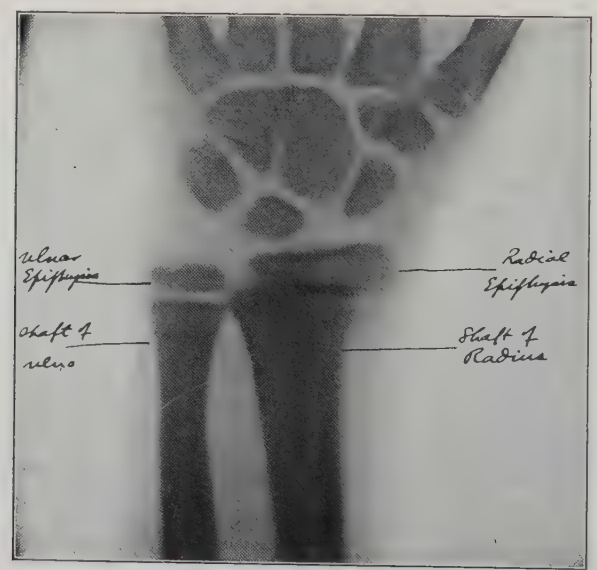


Fig. 608.—Note lateral displacement of separated lower radial epiphysis. Child about eight years old (M. G. H., Dodd).

If the fragments are widely separated the orbicular ligament is probably torn, and immediate operation upon the subsidence of the primary swelling is wise. Displaced fragments impede movement.

In operating, the fragments of bone should be removed, and when the exact conditions are seen a complete resection of the head of the radius done. Operation is indicated with a complicating irreducible dislocation of radius or ulna or both.

After the primary immobilizing splint is removed the elbow will be found to be pretty stiff. Gentle massage and passive motion and attempts at

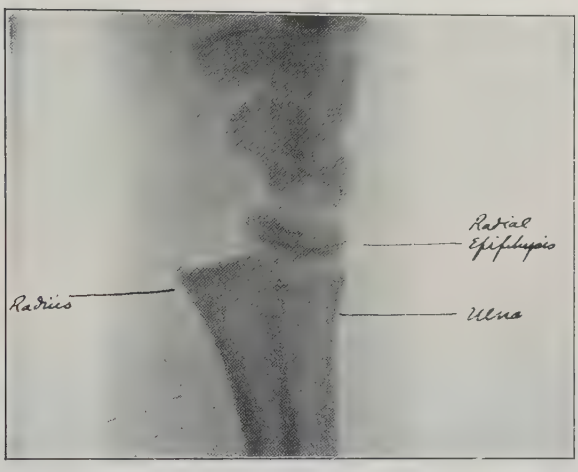


Fig. 609.—Note dorsal displacement of separated lower radial epiphysis. Child about eight years old (M. G. H., Dodd).

active motion should, within four to eight weeks, result in approximately normal elbow movements.

Operation should be undertaken in those overlooked old cases in which non-union, malunion and adhesions, and excessive callous formation and a

Fig. 610.—Manner of grasping forearm to detect the presence of fracture. Note the firmness of grasp.

displaced fragment have resulted in impairment of the usefulness of the forearm and elbow.

Fracture of the Shaft of the Radius (see Figs. 615–619, inclusive).—This is usually caused by direct violence.

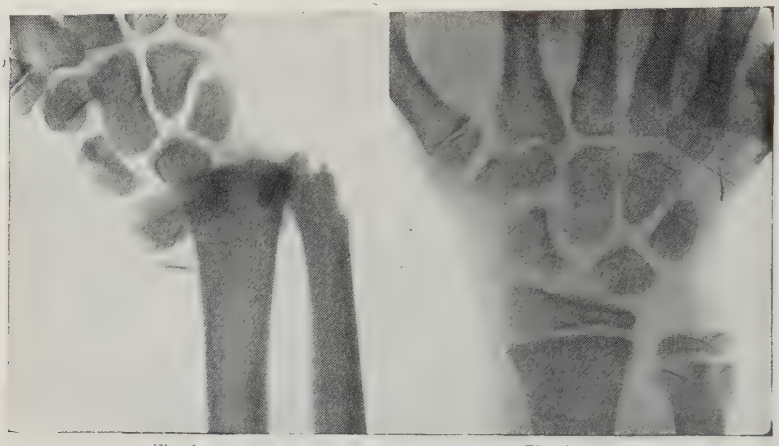


Fig. 611. Fig. 612.

Fig. 611.—Separation of the lower epiphysis of both radius and ulna and fracture of the lower end of ulna through base of styloid process of ulna. Note lateral displacment to radial side of both fragments.

Fig. 612.—Same as Fig. 611. Fragments replaced by manipulation without incision.

Fig. 613.—Greenstick fracture of both bones of the right forearm. Note uniform bending of the forearm.

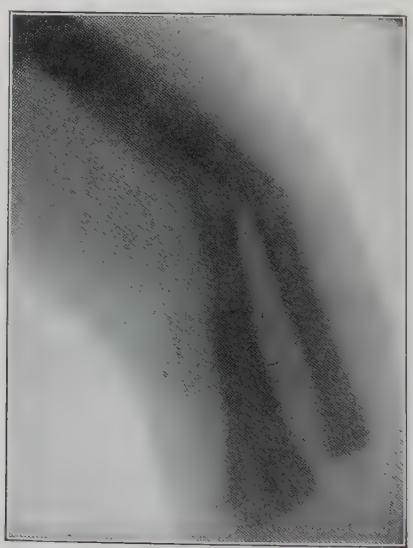


Fig. 614.—Greenstick fracture of both bones of the forearm of a child. Same as Fig. 613.

The back-fire fracture, or the fracture from a kick-back of an automobile crank handle, the chaffeur's fracture, is not a constant lesion. The sites of fracture in the order of frequency as analyzed in a large group of cases is as follows: in the lower third of the radius; one of the carpal bones—the

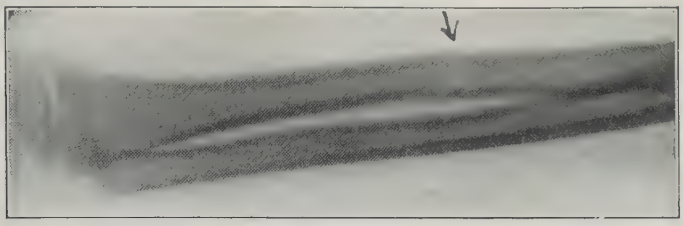


Fig. 615.—Lateral view of a greenstick fracture of the radius.

scaphoid usually; through the level of the lower radial epiphysis; through the ulnar styloid process and the radial epiphyseal line.

After this injury 25 per cent. of the cases showed only damage to the soft parts (Bizarro).

The fracture occurring at any part of the shaft presents no unusual symptoms. The head of the bone does not rotate with the shaft unless the fragments are locked. Abnormal mobility, pain, and crepitus are present. The displacements vary with the situation of the fracture. Pronation and supination will be limited and painful. This fracture has been mistaken for a subluxation of the radial head. A fracture of the radial shaft at the junction of the lower and middle thirds will sometimes suggest very plainly the lateral deformity in a Colles fracture, the prominent ulna and apparently

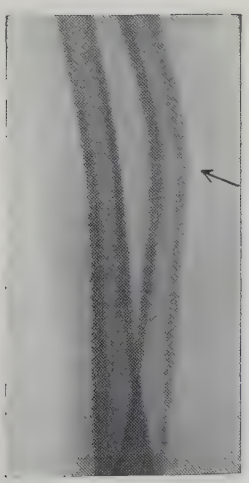


Fig. 616.—Greenstick fracture of the ulna. Arrow points to the site of fracture. Note the bending of both radius and ulna and crack in convexity of the bent ulna.

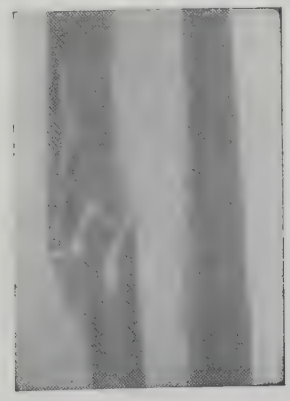


Fig. 617.—Comminuted fracture of radius. An unusual type more often seen in the lower leg.

shortened styloid process of the radius being in evidence. If the fracture occurs in the upper third of the bone, the displacement of the upper fragment will be considerable.

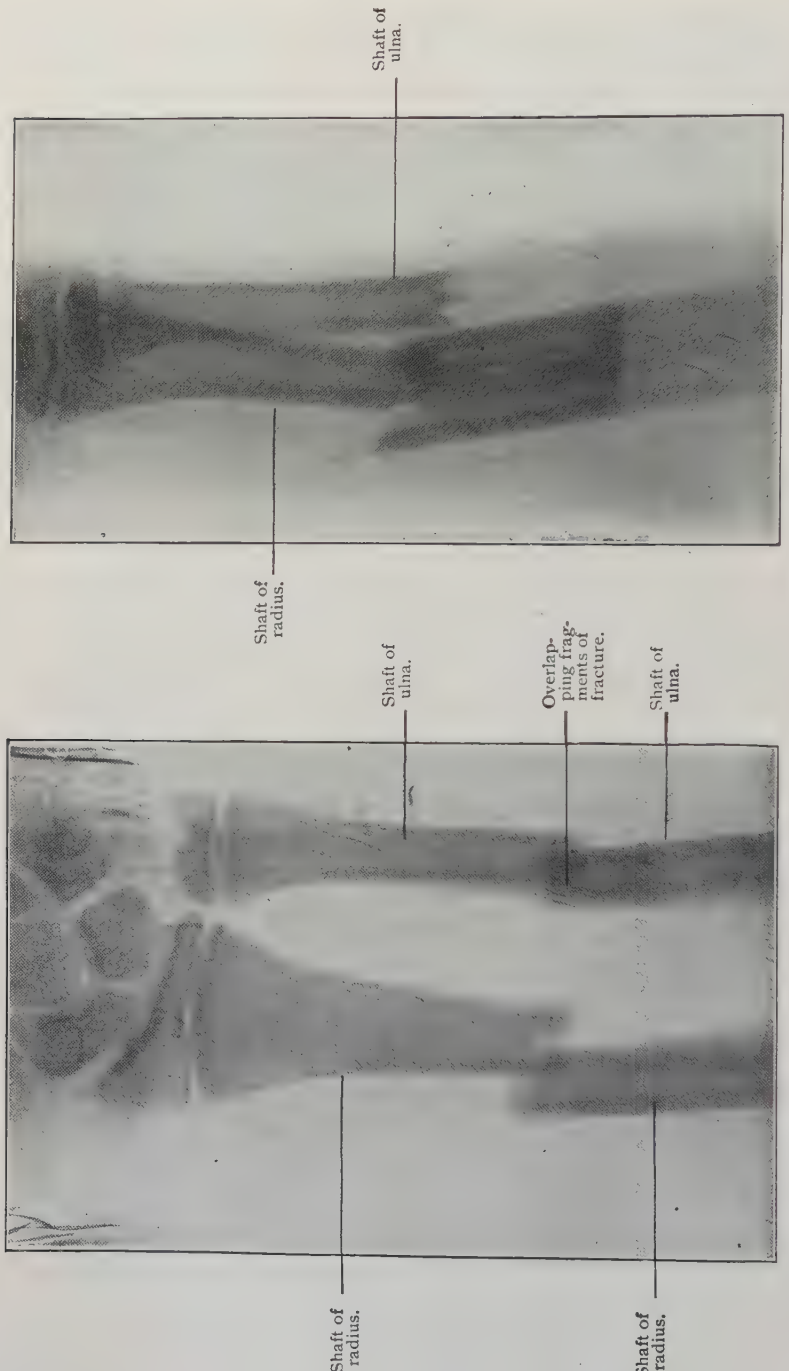


Fig. 618.—Fracture of both bones of the forearm. Notice displacement and overlapping of fragments. Notice epiphysis of lower end of radius and ulna. Anteroposterior view. Figures 618, 619 emphasize need for two plane rays.

Fig. 619.—Same as Fig. 618. Lateral view. Notice displacement of fragments and overlapping. This overlapping is very difficult to overcome.

Separation of the Lower Epiphysis of the Radius.—The lower radial epiphysis unites to the shaft of the bone at the twentieth year. Previous

to this age a separation of the epiphysis is not at all uncommon. Many cases of separation of this epiphysis are thought to be Colles' fractures, and they are treated as such.

A soft, cartilaginous crepitus is felt. There are usually less swelling and less pain than in a Colles fracture. The deformity is quite constant: a prominence near the carpus on the dorsum of the wrist and a prominence higher up on the palmar surface of the wrist. If the epiphysis is displaced without any fracture of the diaphysis recurrence of deformity is quite likely after reduction. If a few bony spicules are attached to the replaced epiphysis recurrence of deformity following reduction is less likely. It is often quite difficult to secure absolutely perfect reduction of the epiphyseal fragment.

In a large percentage of Colles' fractures the styloid of the ulna is broken. In separation of the radial epiphysis the ulna is broken a bit higher in the shaft. In Colles' fracture there is ordinarily a radial deviation of the hand which is absent in epiphyseal separation. The lower radial epiphysis is displaced dorsally backward. The periosteum stripped from it is attached at the dorsal attachment of the shaft. This stripped periosteum accounts for the dorsal bone mass being so great as compared with the palmar bone mass.

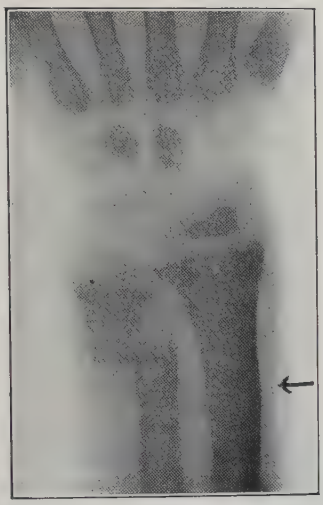


Fig. 620.—Transverse fracture of the ulna and radius. Much displacement of ulnar fragment.

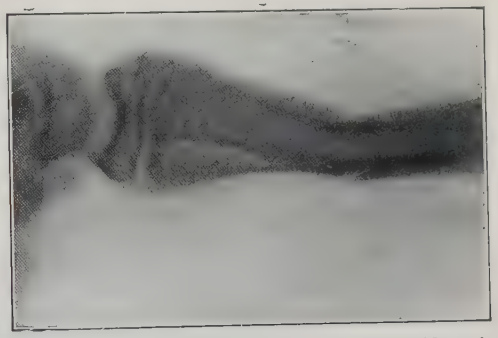


Fig. 621.—Same as Fig. 620. Lateral view. Note the anteroposterior deformity. An *x*-ray should always be taken in at least two planes.

It is almost impossible to reduce a separated lower radial epiphysis after two or three weeks have elapsed until this excessive callous mass is divided.

A little bone tissue may accompany the displaced epiphysis broken from the distal end of the diaphysis. Interference with growth following separation of the epiphysis is considered in Chapter XXXVII, page 1062. There is no doubt that nature compensates for deformity following separation of this epiphysis. M. K. Smith has reported two cases: A boy of thirteen with marked deformity from dorsal displacement seen two weeks after the accident. Attempted reduction under general anesthesia was unsuccessful. Nine months later there was no apparent difference between the two wrists.

A girl of eight with a dorsally displaced lower radial epiphysis appeared eleven days after the injury. Reduction under a general anesthetic was impossible. After five months there was some improvement in the appearance of the wrist. Two years subsequently the Roentgen ray and clinical examination showed almost no deformity of the wrist.

Nature does make up for displaced epiphyses very largely. This should not prevent the surgeon from completely reducing the displacement.

Treatment.—The usual dorsal displacement of the epiphysis requires forcing the epiphysis down over the end of the diaphysis. The pushing of the epiphyseal fragment into position may be facilitated by traction downward on the hand.

Zadek[1] finds that there is a tendency to recurrence of the deformity because of the smooth cartilaginous surfaces offering no serrations to hold the fragment in place.

Zadek calls attention to the fact that forced palmar flexion of the wrist through the pressure brought to bear on the fragment by the tense extensor tendons, together with the position itself of flexion of the wrist, hold securely the replaced epiphysis. A circular plaster-of-Paris splint seems to maintain the flexed position. This splint should extend from the metacarpophalangeal joints to the middle of the forearm. If two or three weeks have elapsed after the injury, open reduction of this displacement is indicated. The operation should be conducted as for an old unreduced Colles' fracture.

Zadek emphasizes the wisdom of approaching such an injury laterally rather than through a dorsal incision. The large dorsal callus would render difficult the approach to the line of bone cleavage.

After the operation of freeing the epiphyseal fragment the wrist should be retained in palmar flexion as after reduction of recent separations. Retention of the splint for two weeks will secure firm union.

Fracture of the shaft of the ulna, with or without radial head dislocation, occurs usually because of a direct blow received upon the arm raised for protection. It is more uncommon than fracture of the radius (see Fig. 616). It is easily compound.

Localized tenderness, pain upon attempting to use the forearm, obscure discomfort in the arm after an injury—these may be the only signs of fracture. There is no general swelling of the forearm. Ordinarily, there will be very little displacement, because the radius serves as a splint for the broken bone. Crepitus may be detected if the ulna is grasped between the fingers, placed either side of the fracture, and motion is attempted. The shaft of the ulna being subcutaneous throughout its entire extent, the tender seat of fracture can be determined easily (see Fig. 654).

Fracture of the coronoid process of the ulna is associated with backward dislocation of the ulna. It is a rare accident. A very small fragment is broken off, and it is not much displaced. If in any dislocation of the forearm backward recurrence of the deformity after reduction occurs readily, a fracture of the coronoid should be suspected. This will be confirmed by

[1] Archives of Surgery, May, 1925, p. 969.

the discovery of a small hard mass in front of the elbow-joint just above the insertion of the brachialis anticus muscle; roughly, a fingerbreadth above the bend of the elbow. This small hard mass may give crepitus upon being manipulated. It is very difficult to detect this fragment of the coronoid process even under the most favorable conditions. The Roentgen ray may discover it.

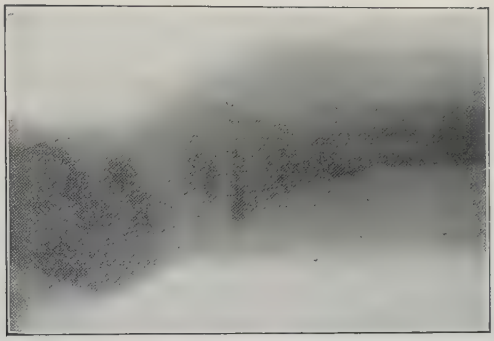


Fig. 622.—Greenstick fracture of ulna and radius. Lateral view of Fig. 623.

Fracture of the Bones of the Forearm Classified According to the Relation of the Fracture to the Insertion of the Pronator Radii Teres Muscle.—If the fracture is *above* the pronator radii teres and below the insertion of the biceps, the fragments will be acted upon by the pronator radii teres, pronator quadratus, the biceps, the supinator brevis, and the supinator longus. Both powerful pronators are attached to the lower fragment. The quadratus

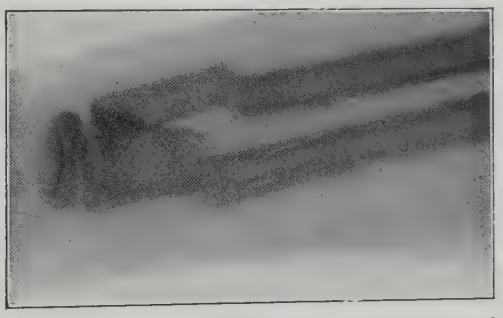


Fig. 623.—Lateral view of Fig. 622. Note the considerable displacement of fragments. A difficult fracture to reduce and hold reduced unless the fragments can be locked in position. Almost impossible to lock fragments of both bones without an incision and digital pressure.

and radii teres and supinator longus all pronate the lower fragment and pull it over against the ulna.

The *upper fragment* is pulled by the biceps anteriorly to the lower fragment and it is supinated and flexed by the supinator brevis. There will be therefore extreme displacement of the two ends of the fragments with very little external deformity.

The *lower fragment* will be pronated and the upper fragment supinated.

If the fracture is *below* the pronator radii teres and the biceps, the *upper fragment* is pulled forward and upward by the biceps (see Fig. 655). The supinators and the pronators will be opposed. The lower end of the upper fragment will be pulled toward the ulna. The supination of the upper fragment will be marked.

The *lower fragments* will be pulled together and the radial fragment strongly pronated, a pronation of the lower fragment and a supination of the upper fragment. In addition to these definite muscularly balanced displacements it must never be forgotten that the original direct violence will contribute its influence to the muscular factors in the resulting displacements.

Fig. 624.—Fracture of both bones of the forearm at different levels. Attempted traction, repeatedly made, failed to secure apposition of fragments. Incision and reposition finally was successful with good functional result, as well as good anatomic result.

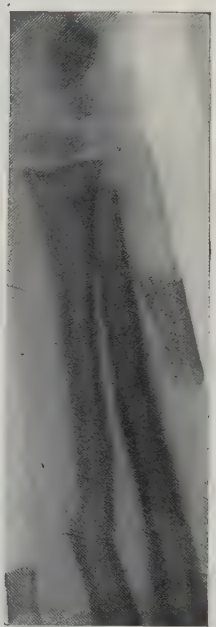


Fig. 625.—Lateral view of Fig. 624.

The carefully taken anteroposterior and lateral Roentgen-ray stereoscopic plates will exactly measure the problem of reposition.

Treatment of Fractures of the Forearm.—The objects of treatment are to prevent permanent deformity and to preserve the movements of pronation and supination.

Fracture of Both Radius and Ulna.—The necessity of securing normal movement at the upper and lower radio-ulnar joints, after fracture of the shafts of the radius and ulna, is so important and this movement may be so greatly impaired by deviations of the four fragments concerned that it is

essential not only to secure alignment of shaft fragments of the respective bones, but also to place fragments in end-to-end apposition.

Time for Reduction.—The surgeon should not wait for the swelling to appear and subside; neither should he wait ordinarily for the swelling which has appeared to subside. The quickest subsidence of swelling associated with fracture of the forearm will be brought about by immediately reducing the fractured fragments. The earlier after fracture the reduction is attempted, the easier will it be to bring about reduction.

The earlier the fracture is reduced, the better will be the repair of the fracture. The more accurate and immediate the reduction, the minimum will be the amount of the callus. In the forearm a minimum callus is desirable. Therefore replace the fragments early in exact reposition.

Whipple and St. John made important observations upon the microscopic appearances of the tissue forming between fractured forearm frag-

Fig. 626.—Fracture of both bones of the forearm. Note patient lying on back; countertraction in axilla and against chest wall; hitch around wrist; manipulation of forearm with free hands (Magnuson).

ments at successive stages of the reparative process. These observations confirm the importance of an early immediate reduction of the fracture as almost a *sine qua non* to successful treatment.

Anesthetic.—A general anesthetic should always be used in attempting the reduction of displaced fragments of fractures of both bones of the forearm.

The general anesthesia causes: (1) Muscle relaxation absolutely essential to a successful reposition of a fracture; (2) eliminates pain, a most desirable thing; (3) enables the surgeon to proceed with the attempted replacement deliberately and carefully and not hurriedly.

The *lower fragment* will be pronated and the upper fragment supinated.

If the fracture is *below* the pronator radii teres and the biceps, the *upper fragment* is pulled forward and upward by the biceps (see Fig. 655). The supinators and the pronators will be opposed. The lower end of the upper fragment will be pulled toward the ulna. The supination of the upper fragment will be marked.

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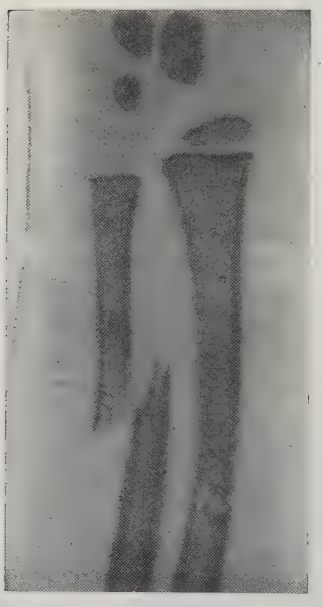

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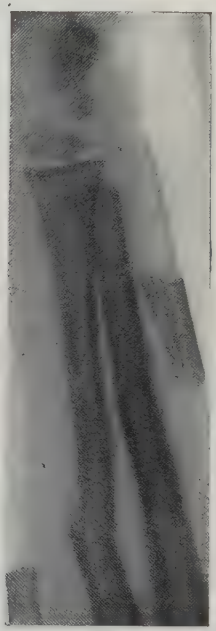

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Anesthetic.—A general anesthetic should always be used in attempting the reduction of displaced fragments of fractures of both bones of the forearm.

The general anesthesia causes: (1) Muscle relaxation absolutely essential to a successful reposition of a fracture; (2) eliminates pain, a most desirable thing; (3) enables the surgeon to proceed with the attempted replacement deliberately and carefully and not hurriedly.

In young children under ten years nitrous oxid and oxygen may give the desired relaxation. In individuals over ten years of age and in adults the administration of ether will prove more satisfactory.

Fluoroscopic reduction is absolutely essential. As Whipple and St. John[1] point out, all surgeons acknowledge that the advantage of the reduction of a fracture by vision is helpful. The fluoroscope adds to the facility of the surgeon by making the fragments visible. Palpation of the fragments alone is not equal to the visible maniptlations.

There are four fragments to deal with and the surgeon will be obliged to use his mechanical sense and ingenuity in manipulation, traction, and angulation in order to reduce first two fragments and then two other fragments. The Roentgen ray will assure the surgeon that fragments which have been reduced do not slip. Following the reduction of the fracture a Roentgen-ray record should always be made.

Adequate Assistants.—The surgeon should not attempt any fracture treatment without a sufficient number of trained assistants. No surgeon should operate without trained assistants. The attempted reduction of the four fracture fragments of the radius and ulna is a major surgical procedure demanding all the necessary available skill possible. At least four men are needed, viz., the surgeon, an anesthetist, one assistant to maintain traction, one assistant to maintain countertraction, and to assist the surgeon in the manipulations made. The help of a Hawley table is a great advantage.

It is important to complete the reduction of the fragments the first day, particularly is this true in the case of a fracture of the forearm in a child.

It is unwise to postpone reduction even for a day or two because the retraction of fasciæ, the round-cell infiltration of the soft parts, the rigidity of shortened muscles, the swelling of the soft parts will all hinder and render difficult a reduction that is postponed.

Whipple and St. John have used and secured by the following method splendid results:

Position of Forearm.—According to the site of the fracture and the presence of overriding of fragments the following position is used:

If the fracture is in the *upper third* of the forearm, supination and flexion of the elbow to a little beyond a right angle (that is, in acute flexion). In any other part of the shaft midpronation and supination and flexion of the elbow to a little beyond a right angle is desirable.

If the fracture is in the upper third and the arm is to be put up in supination and flexion it can be done easily by a circular plaster-of-Paris bandage splint.

If the fracture is elsewhere in the shafts of these two bones the "sugar-tong" plaster-of-Paris splint is to be used. This sugar-tong splint (see Fig. 647) prevents rotation of the forearm, keeps the flexed elbow under control, permits of lateral pressure being exerted if necessary during the first two weeks when the process of repair is young.

[1] Surg., Gyn., and Obst., vol. xxv, 1917, p. 77.

Method of making the sugar-tong splint (Whipple and St. John):

A strip of Canton flannel is cut equal in length to the distance from the metacarpophalangeal joints on the palm of the hand around the forearm, including the elbow to the knuckles. This measurement is taken with the elbow at a right angle and including the epicondyles of the humerus.

Plaster-of-Paris bandage is rolled into a strip 1 inch shorter than the flannel strip. The plaster strip is then laid over the dry Canton flannel strip, leaving the flannel side out to come in contact with the skin of the patient.

The splint is then applied to the forearm, after reduction of the fracture, with the forearm held in semipronation and supination, and with the elbow held at slightly less than a right angle.

The splint is then bandaged snugly to the forearm while the plaster is still soft and it is left bandaged in this way for fifteen or twenty minutes until the plaster is set and hardened, when the bandage is cut down and a looser bandage is applied.

The forearm is then supported in a *sling* and after a record roentgenogram is made the patient is sent home to report always the next day or immediately if he has pain or there is swelling or numbness of the hand or fingers. The splint should not interfere with the patient's ability to make a fist.

Tight bandaging cannot be guarded against too carefully.

This "sugar-tong" splint (see Fig. 647) suggests the equally useful Stimson plaster-of-Paris strip splint used in fractures of the leg near and at the ankle-joint (see Fig. 1289).

The *after-treatment* of fracture of the forearm using the "sugar-tong" splint: The patient should be seen daily for the first three or four days. The two parts of the splint are removable. Massage and moving fingers are possible immediately. The forearm is allowed to rest in one part of the splint while access is had to the arm after displacing the other part of the splint.

During the second and third week carefully guarded active and passive movement is instituted. The splint should be used four or five weeks if there was a complete fracture. The arm should be supported by a bandage or sling for the security it affords until the patient has confidence in using the forearm freely and painlessly.

The results of the above treatment in forearm fractures justifies its employment under the conditions specified.

In 100 cases in children and young adults good anatomical and functional results were obtained in from 98 to 100 per cent. of the group (Whipple and St. John).

Complicated Displacements.—It is quite apparent that when there exists a somewhat complicated displacement of the four ends of the fragments it may be almost impossible to reduce these fractures by simple traction and manipulation and immediate rigid fixation.

Magnuson's Method is here applicable. It is based on the fundamental principle that traction and countertraction will overcome muscle pull on the fragments and that their reposition in appropriate positions will accomplish the reduction (see Fig. 626). *Bed traction*, with the suspension of the forearm and the elbow flexed to a right angle, will eliminate the sagging pull of gravity on radius and ulna, the biceps is relaxed, and its supinating and

flexing effect on the upper fragment of the radius is eliminated. The traction at the wrist will help to align the fragments (see Fig. 628).

Countertraction may be increased beyond the weight of the upper extremity by adding a weight to the upper arm.

Magnuson's method of controlling supination and pronation is effective and simple (see Figs. 628–630).

The extension is applied so the patient can move the hand freely, but so that pronation and supination are under the control of the surgeon and not under the control of the patient.

Two pieces of wooden lath or splint wood cut the right length serve as spreaders, and placed at the level of the metacarpophalangeal joints help to control supination and pronation of the distal fragments.

The *use of a circular plaster-of-Paris splint* may be effective and convenient in certain forearm fractures, provided, of course, that care be exercised not to compress the loose fragment ends together and

Fig. 627.—Method of making a hitch for holding the arm in traction on a fracture of both bones of the forearm (Magnuson).

Fig. 628.—Fracture of both bones of the forearm. Suspension treatment with traction. Note arrangement of cross splints for hand and the attachment of traction adhesive plaster (Magnuson).

provided the plaster be split and made a bivalve splint. It thus becomes a splint somewhat resembling the sugar-tong splint of Whipple and St. John.

In order to immobilize a fracture of the shaft of the radius not only must the fracture itself be held firmly, but the joint immediately above and below the seat of fracture must be immovably fixed. If the arm is seen immediately after the accident, and the soft parts are not evidently bruised, and there is little swelling, a plaster-of-Paris splint should be applied. It should extend from the axilla above to the metacarpophalangeal joints below.

The arm should be flexed to a right angle and the forearm semisupinated (thumb upward) (see Fig. 636).

Whether the forearm should be placed in full supination or in semipronation will depend upon where the fractures of the radius and ulna are located. Obviously, the movement of supination is the most useful movement to be preserved. If the arm is placed in supination probably much of the movement of supination will remain after union of the fracture. If placing the arm in supination causes a great increase in the bony displacement, then that position which will assist in the maintenance of reduction

Fig. 629.—Fracture of both bones of the forearm. Note rope attached to laths to hold forearm in any degree of pronation or supination desirable (Magnuson).

Fig. 630.—Fracture of both bones of the forearm. Anterior and posterior splints applied with broad strips of adhesive plaster to assist in holding fragments (Magnuson).

should be used. A little potential movement in supination may have to be sacrificed in order to correct the bony deformity. If the bony deformity is corrected, then will follow the greatest possible amount of motion practicable.

Precautions in Using the Plaster-of-Paris Splint.—The forearm should be held in the corrected position by an assistant throughout the application of the plaster bandages. Two assistants will facilitate the putting on of the plaster. The forearm and upper arm should be thinly covered with one layer of sheet wadding; cotton wadding should not be used. No salt should be used in the water in which the plaster bandages are dipped. It will require about three or four bandages, 3 inches wide and 4 yards long,

for an ordinary muscular adult arm. The plaster roller should be applied deliberately, evenly, and snugly from the metacarpophalangeal joints to the axilla. Great lateral compression of the arm will be avoided if the bandage is applied as directed. There will be insufficient compression to crowd the bones together and so produce deformity. Always split the plaster-of-Paris splint.

After-care of the Plaster Splints.—When the plaster has set firmly the assistant may place the forearm in a sling of comfortable height to support the arm. Inspection of the fingers will determine the condition of the circulation in the limb. It is always wise to *immediately split* an encircling plaster splint and thus avoid all danger of a too tight splint.

The immediate splitting of the encircling plaster splint should be done so as to bivalve the plaster case. The bivalving should be done so as to make

Fig. 631.—Fracture of radius. Little apparent displacement.

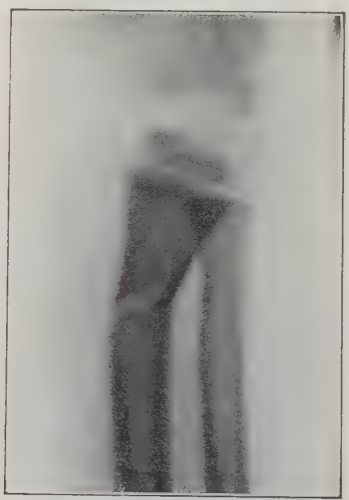

Fig. 632.—Fracture of shaft of radius. Lateral view of Fig. 631. Real displacement seen in this view.

either two splints, upper and lower, or two lateral splints. The type of bivalve will be determined by the seat of fracture, the character of the displacement of fragments, the completeness of the reduction, and the efficiency of the immobilization of the splint.

If there is too great pressure, if the splint is too tight, a blueness will appear, indicating a sluggishness in the circulation. If this sign appears, the splint should immediately be split from axilla to hand by a knife. This will relieve the circulation. Ordinarily there is no difficulty of this sort. The patient should be seen each day for the first week after the dressing is put on. Inquiry should be made for pain and throbbing in the arm and sleeplessness, which are evidences of too great pressure. If the arm is doing well, the splint should cause no discomfort. After one week the plaster splint should be removed. A Roentgen ray record should be made now, while the fragments can be without too great resistance relatively changed

if necessary, for the swelling of the arm will have diminished and the splint will have become loosened. Unless this loosening is corrected, an opportunity for deformity to occur will then exist. Either a new plaster should be applied or the old splint, if suitable, should be reapplied and tightened by a bandage. If the splint is too large, it may be made smaller by removing a strip of plaster the entire length of the splint. The edges of the cut plaster should be bound with strips of adhesive plaster to prevent chafing of the skin and crumbling of the plaster. The position of the bones at the seat of fracture should be noted. The degree of movement possible at the seat of fracture should be noted. At the end of each week the splints should be removed. After about

Fig. 633.—Variations in the shape and width of the interosseous space between radius and ulna when the forearm is semipronated, supinated, and pronated. Semipronation presents the widest interosseous space.

three weeks, when union is well advanced, the plaster splint may be cut off below and the upper part discarded, or a posterior splint of wood may be applied for lightness and convenience.

The Use of Anterior and Posterior Splints of Thin Wood, Well Padded.—If the force was a direct violence and there is injury to the soft parts, if the swelling is considerable and is likely to be greater, it will be best to use palmar and dorsal splints of wood upon the forearm and an internal right-angle splint at the elbow. The forearm is held in the position of semisupination (see Fig. 636). The maximum swelling occurs within the first forty-eight hours, barring, of course, inflammatory disturbances, which are not to be considered

here. The splints should be of thin splint wood which is stiff enough not to yield to ordinary pressure. In width they should be $\frac{1}{4}$ inch wider than the forearm. The posterior splint should extend from just above the middle of the forearm to the metacarpophalangeal joints. The anterior splint should extend from the same point on the forearm to the middle of the palm of the

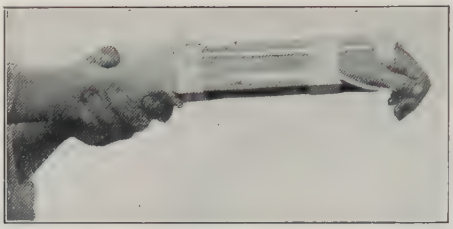

Fig. 634.—Fracture of the forearm low down, or Colles' fracture. Anterior and posterior splints, three straps, radial pad. Anterior splint cut out to fit thenar eminence.

hand (see Figs. 634, 635). The palmar splint is cut out on the thumb side, so as to avoid pressure on the thenar eminence. These two splints are padded with evenly folded sheet wadding no wider than the splints. About three or four thicknesses of the sheet wadding will be necessary. The posterior splint is padded alike throughout its whole extent. The anterior splint is so padded as to conform to the irregularities of the anterior surface of the

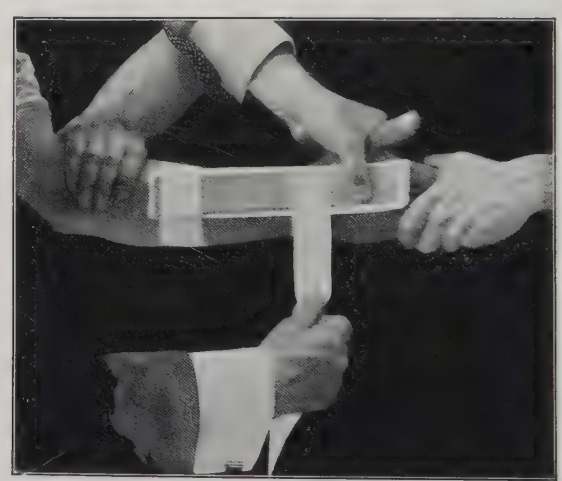

Fig. 635.—Fracture of the forearm. Manner of holding arm and of applying the adhesive-plaster straps. Posterior splint of splint wood.

forearm, particularly at the radial side near the wrist. The internal right-angle splint is padded evenly with four thicknesses of sheet wadding. It overlaps the wooden splints and extends up to the axilla. It immobilizes the elbow-joint.

The Application of the Wooden Splints.—The forearm is held flexed at a right angle and semisupinated (see Fig. 635) and steadied by an assistant. The posterior and then the anterior splints are applied to the forearm. Three straps

of adhesive plaster, 2 inches broad, are then applied, one at the upper ends of the splints, one at the wrist, and the third across the palm of the hand and around the posterior splint only. These straps should simply steady the splints snugly in position (see Fig. 635). The bandage is next applied, and it is by this that pressure is exerted upon the arm. There should be some spring left upon pressing the splints together after the bandage is applied. If there is none remaining, too great pressure will be made on the arm and the circulation will be interfered with. The arm is placed in a sling of comfortable height (see Fig. 636).

If the fracture of the forearm is above the middle of the bones, the tin internal or anterior right-angle splint should be used to immobilize the

Fig. 636.—Fracture of both bones of the forearm. Proper position of arm in sling. Note hand is unsupported by sling, and arm rests on ulnar side. Notice height of arm.

elbow-joint. This should be applied after the wooden splints are in place and while the arm is semisupinated. A bandage is then placed over both wooden and tin splints (see Figs. 641, 645, 646).

Certain fractures, it is not always easy to state which, of both bones of the forearm are best reduced and held with the elbow in complete or almost complete extension. At the time of the reduction under an anesthetic it can be determined if the complete extended or straight position is desirable. A few fractures of both bones of the forearm are best retained after reduction in flexion less than a right angle.

After-care of Wooden and Tin Splints.—The patient should be seen every day for two or three days after the fracture. The splints should be readjusted and applied more snugly by a fresh bandage. The comfort of the patient should be considered; any complaint on the part of a sensible in-

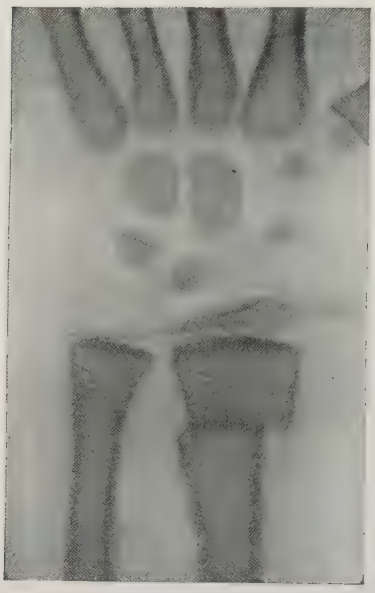

Fig. 637.—Fracture of both bones. Child four years old. Note lateral displacement of radius and overriding of fragments (Dodd).

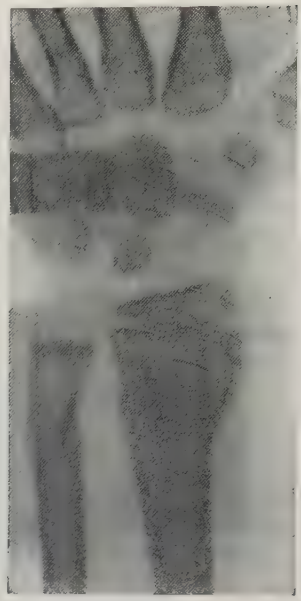

Fig. 638.—Result after reduction by leverage through small incisions (Dodd).

Fig. 639.—Fracture of the forearm, both bones. Note anterior posterior displacement and shattering due to overlapping of fragments (Dodd).

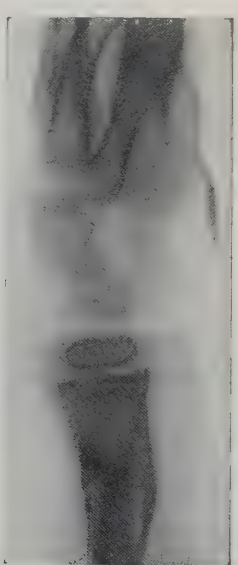

Fig. 640.—Result after reduction by leverage through small incisions (Dodd).

dividual should be inquired into. If the apparatus is applied with the bones in approximately normal position there should be no subsequent discomfort. All splints should be removed at least twice a week throughout active

Fig. 641.—Fracture of both bones of the forearm. Ulnar view of the anterior and posterior splints. Note length of splints and position of straps. Straps of the internal right-angle splint, 3 and 4.

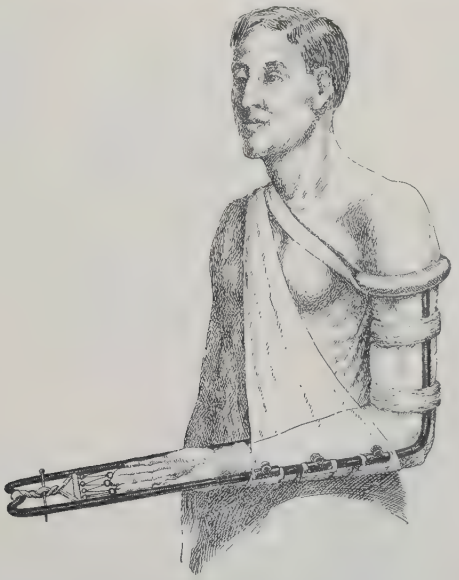

Fig. 642.—Method of using a modified Thomas traction arm splint for the ambulatory treatment of fractures of the forearm. For sake of clearness the bars of the splint have been drawn straight, but in practice it is better to separate them opposite to the hand. The splint is supported by slings in the conventional manner and not exactly as depicted, as the sling passes on the outside of the splint and supporting bands. Countertraction is furnished by the bands about the splint and arm, and traction as shown by the Spanish windlass or by elastics (Blake).

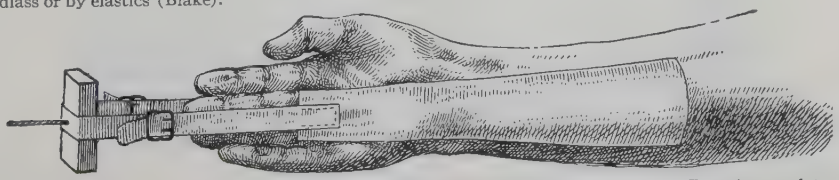

Fig. 643.—Method of attaching glued bands to forearm for traction or suspension. Tape is sewed to the bands, which may be made of Canton flannel or several thicknesses of gauze (Blake).

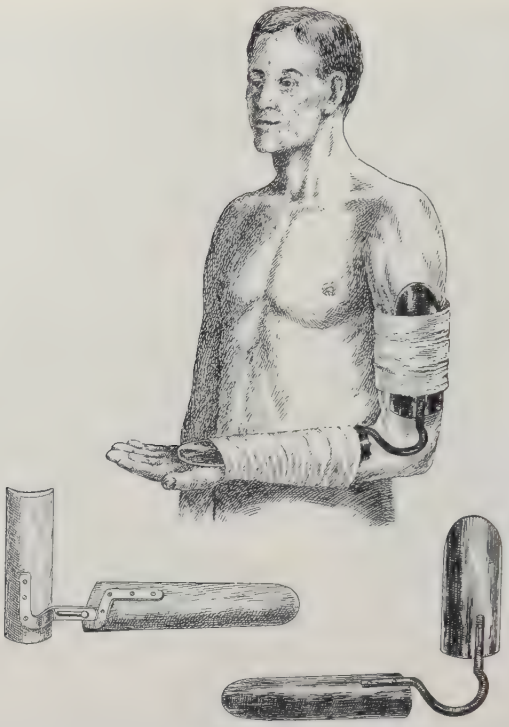

Fig. 644.—Application of the Van der Veld and Sinclair splints for fractures of the forearm. It will be observed that these splints are alike in principle in preventing pronation through the placing of the armpiece on the outer aspect of the arm. The Sinclair splint is made of metal, the Van der Veld of wood, and the latter has a slot and bolt permitting adjustment in angle and length (Blake).

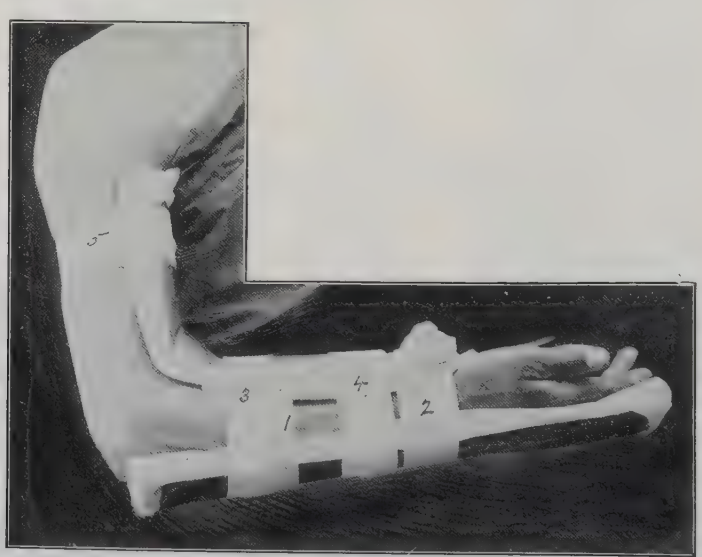

Fig. 645.—Fracture of the bones of forearm. Forearm supinated. Anterior and posterior splints and tin internal or anterior right angular splints. 1 and 2, Straps holding anterior and posterior splints; 3, 4, and 5, straps holding internal right-angle splint.

treatment, and the presence of deformity noted and corrected. After the first week and a half, the swelling having subsided, it is often advantageous to apply in place of these splints of wood the plaster-of-Paris splint, which has been described.

It may be necessary, especially in compound fractures of the forearm, even though displacement of fragments is at a minimum, to apply traction and countertraction as well as suspension of the forearm.

This may be efficiently accomplished by the method shown in Fig. 642, in which a modified Thomas splint is employed with glove extension, if simple retention is sought. The ordinary adhesive tape may be used instead of the glove for traction (Fig. 643). The Van der Veld and Sinclair splints for fractures of the forearm are satisfactory if traction is unnecessary (Fig. 644).

Fracture of the head and neck of the radius and fracture of the coronoid process of the ulna should be treated by the internal or anterior right-angle

Fig. 646.—Fracture of both bones of the forearm. Anterior and posterior splints and tin internal right-angle splint immobilizing elbow-joint. Note arm in semipronation, "thumb up"; position of straps; padding of internal right-angle splint.

splint with the forearm semipronated, that is, with the thumb up (Fig. 646) or in the flexed position.

Fracture of the shaft of the radius, if above the middle of the bone, should be treated by the anterior and posterior wooden splints and the internal right-angle splint. If below the middle of the bone, the internal right-angle splint may be omitted, although it may be well to retain it in most instances. If the fracture is in the upper third of the bone, it may be impossible to correct the deformity without making an open fracture and suturing the fragments together. It may be possible to approximate the fragments by putting the forearm in a position of semipronation. No special splint is necessary to maintain this position; the two wooden anterior and posterior splints and the tin internal or anterior right-angle splint fulfil all the indications. Fracture of the radial shaft alone may often require reposition through an incision. In most cases operated upon retention of the replaced fragment will be wise by a suture, absorbable or not, or a plate or screw.

Fracture of the lower end of the radius may be associated with fracture of the lower end of the ulna, with separation of the inferior radio-ulnar articulation, with a displacement of the lower end of the ulna. Under these associated conditions it will be difficult to hold both fragments

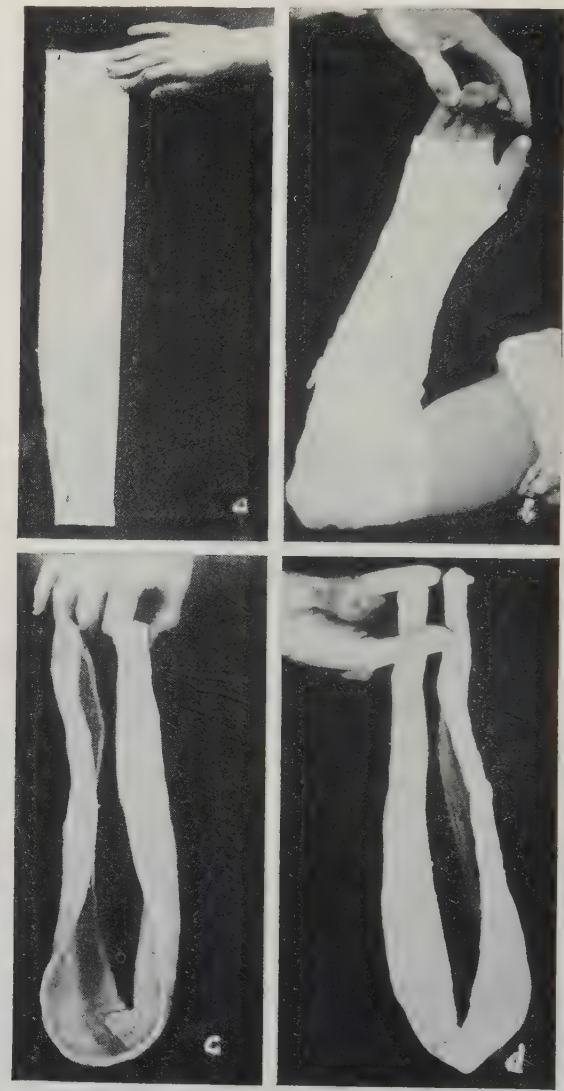

Fig. 647.—*a*, Plaster strip with one edge of the flannel turned over; *b*, the splint applied to the forearm; elbow is seen in flexion and forearm in midsupination; *c* and *d*, the splint removed. The narrow ulnar side of the arm is noticeable as compared with the broader radial side. (Whipple.)

reduced without open reduction. Homans and J. A. Smith call attention to these conditions, and I agree that operative treatment is the best initial treatment.

Separation of the lower radial epiphysis is treated by anterior and pos-

terior splints like those used in the treatment of a Colles fracture (see Fig. 729), or in the flexed wrist position.

Fractures of the shaft of the ulna should be treated so as to restore the shaft of the ulna to its normal anatomy. The ulna is the important bone of the forearm.

In fracture through the upper third of the ulnar shaft the upper fragment is slightly flexed by the action of the brachialis anticus and swings away from the midline, diminishing the carrying angle. Consequently, the relations of the sigmoid cavity are changed, so that if union occurs in this displaced

Fig. 648.—Application of sling. Proper position of triangular bandage in first step: 2 is carried over right shoulder; 1 drops over left shoulder; 1 and 2 are fastened behind the neck; 3 is brought forward and pinned, as shown in Fig. 649.

Fig. 649.—Application of sling. Final position of arm. Two ends tied behind neck and the third end pinned.

position of the upper fragment flexion of the elbow will be materially impaired (Cohn).

The splint made by applying a plaster strip to cover the arm on two sides, as seen in Fig. 647, passing as a loop behind the elbow, is at times useful—the "sugar-tong" splint.

How long should splints be kept on in fractures of the forearm? Until union is firm enough between the fragments so that firm pressure does not cause motion at the seats of fracture. When the fracture is firm, ordinarily after about two weeks and a half, the anterior and internal angular splints may be omitted, the posterior splint alone being left in place. If the posterior splint of wood is used, a broad (4-inch) strap of adhesive plaster, in

addition to the two ordinary straps at each end of the splint, should be placed at the seat of fracture and a gauze bandage applied over all. At the end of the fourth or fifth week all splints should be omitted. Continual watchfulness is demanded in order that bowing at the seat of fracture may not take place. The application of the sling after the omission of

Fig. 650.—Fracture of radial shaft. Slight impaction on palmar surface of the shaft.

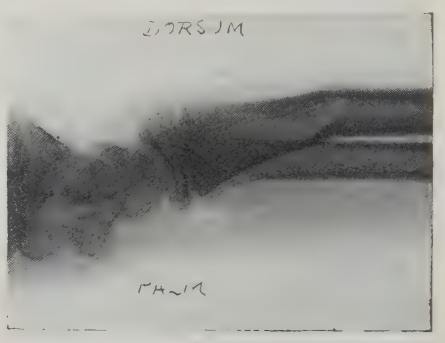

Fig. 651.—Fracture of radial shaft. Note bending with impaction on palmar surface.

Fig. 652.—Anteroposterior roentgenogram: Linear fracture of radial shaft without displacement (Arial George).

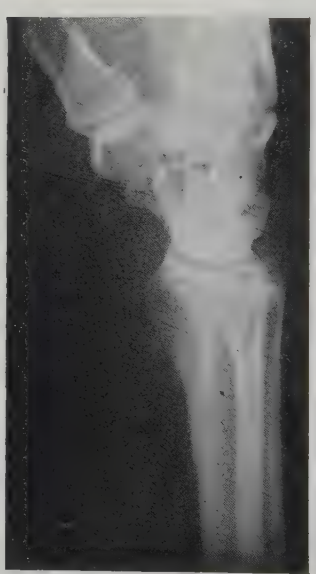

Fig 653.—Lateral roentgenogram of same case as Fig. 652. Note situation of fracture line. No displacement (Arial George).

splints should be carefully made so as to avoid backward bowing of the bones. A laboring man should not go to work for at least from four to six weeks

after leaving off splints. A return to work too early causes bowing of the fracture and pain in the arm.

Massage and passive motion should be employed as soon as union is firm and the anterior and internal angular splints can be removed without allowing displacement. Massage may be given at first without removing the arm from the splint. Convalescence will proceed more rapidly in consequence of massage.

Fig. 654.—Fracture of the shaft of the ulna below its middle. Note that the lower fragment is drawn to the radial side of the forearm by the pronator quadratus muscle. Note muscles brachioradialis, flexor carpi ulnaris, pronator radii teres (after Davis-Peotti).

Fig. 655.—Fracture of the shaft of the radius below insertion of pronator radii teres muscle. Note displacement of the upper fragment forward. Note muscles brachioradialis, pronator quadratus, pronator radii teres, biceps (after Davis-Peotti).

When will the arm be restored to normal usefulness? It is impossible to answer this question accurately. The conditions in each individual instance of fracture are so variable that no general statement can be made that will more than indicate the probable time of convalescence. It may be fairly stated that in an uncomplicated fracture of both bones of the forearm the arm will be useful for working in from two to three months from the time of fracture.

Prognosis and Result of Treatment.—Results of the method of Whipple and St. John should be consulted. There may be some limitation of su-

pination and pronation immediately after the splints are removed. As the callus diminishes and with persistent movements of the arm in ordinary use

Fig. 656.—Compound fracture and dislocation at the wrist. Hand saved.

this limitation should diminish, and in most instances entirely disappear. If the fracture is in the upper or lower thirds of the bones the limitation of

Fig. 657.—Transverse fracture of the radius and ulna with slight displacement.

Fig. 658.—Transverse subperiosteal fracture of both radial and ulnar shafts. No lateral gross deformity.

motion will often be greater than when the fracture is at the middle of the bones. The interosseous space is greatest at the middle of the shafts (see Fig. 633); consequently, callus at this point is less likely to impair motion of the

forearm. The arm should be straight. Movements of the wrist and elbow should be perfectly normal.

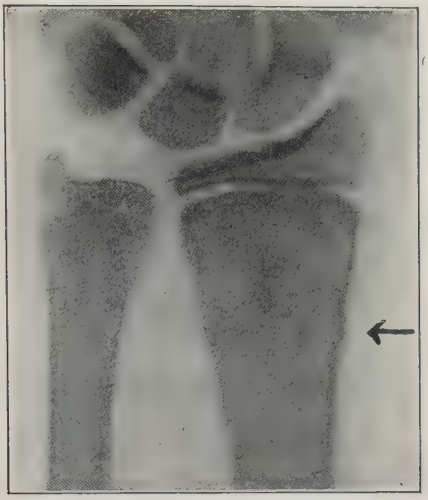

Fig. 659.—Transverse fracture of radius, subperiosteal.

Treatment of Greenstick or Incomplete Fracture of the Bones of the Forearm.—It is impossible to maintain the correction of the deformity if the

Fig. 660.—Old ununited fracture of the radius. Note the space between the fragments, the abduction of the whole hand, the shortening of the radial side of the arm, the atrophy and thinning of the bone of the carpus, and the two radial fragments as indicated by the light shadow of these parts.

bones are simply bent back into position. Even with the greatest care in the use of pads and pressure the deformity will in part reappear. It is neces-

sary, therefore, to administer an anesthetic and to make a complete fracture of the greenstick fracture. This done, the arm is set as in a complete fracture. The best method of refracturing the greenstick fracture is to bend the arm with the two hands in the direction of the original force.

The anterior and posterior wooden splints may be used with satisfaction. Ordinarily, the plaster-of-Paris splint as applied in complete fractures is the best apparatus. Union in children after fracture is more rapid than in adults. At the end of two weeks union will be found firm. It is well not to omit all apparatus in a child until four weeks have passed. If great caution is needed on account of an extremely active child, the posterior wooden splint should be kept on during the fifth week.

Summary of the Treatment of Fracture of the Shafts of the Radius and Ulna.—Fracture of the shafts of the radius and ulna without displacement should be held adequately steadied until union occurs.

Fracture of the radial shaft alone will often require operation, direct reposition, and absolute internal fixation.

Fractures of the ulna alone are rarely displaced.

Fractures of the shafts of both bones always present difficult problems.

It is important that the shaft of each broken bone be restored as perfectly as possible.

If there is no bony approximation of the ends of the fragments and there are four fragments, or at least not enough approximation to afford rigidity of the fracture so as to keep the muscles under their normal stretch, the muscles will continue to contract until a point of resistance is reached which counterbalances their tone.

Fracture of both bones of the forearm should be immediately reduced under a general anesthetic with traction and countertraction and manual manipulation. If this procedure is successful, the Whipple-St. John (see Fig. 647) "tong" plaster splint or the two wooden splints should be applied.

If there is difficulty in the reduction of the fracture of both bones of the forearm by the above method, bed traction and suspension (Blake-Magnuson) may be used (see p. 388).

If neither of the above methods is successful or if neither method is applicable, then the direct open operative method will prove effective (see p. 883).

FRACTURES OF THE OLECRANON

The normal anatomic relations of the olecranon should be kept constantly in mind. The insertion of the brachialis anticus muscle is into the front and lower part or base of the coronoid process of the ulna. The insertion of the triceps muscle is into the posterior part of the upper surface of the olecranon and into the fascia of the posterior surface of the forearm. The small epiphysis of the olecranon unites to the shaft about the sixteenth year. A direct blow upon the olecranon together with violent muscular contraction of the triceps will produce the fracture. The fracture is usually transverse. A complete transverse fracture of the olecranon always opens

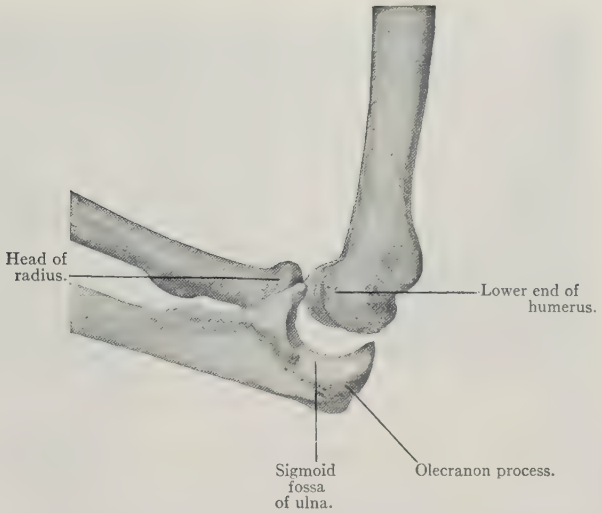

Fig. 661.—Note the great sigmoid cavity and its relation to the olecranon process of the ulna. Almost all fractures of the olecranon are intra-articular.

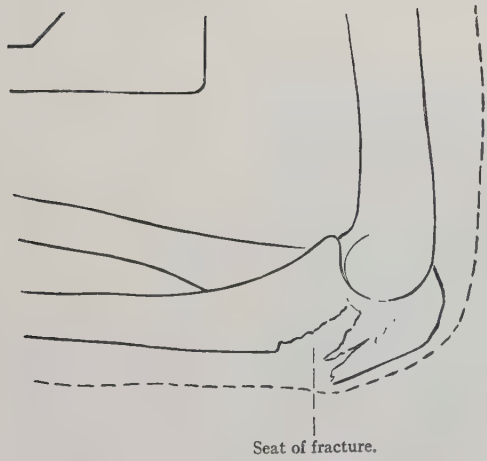

Fig. 662.—Splintered fracture of olecranon without much displacement (Massachusetts General Hospital, 1536. *x*-Ray tracing).

Fig. 663.—Olecranon process fracture. Note the pull through the contraction of the triceps muscle upward. Note the ulnar nerve, internal condyle of humerus, triceps muscle, the external condyle (after Davis-Peotti).

the elbow-joint (see Figs. 661, 663, 668). Some of the varieties of fracture of the olecranon are seen in the accompanying tracings of Roentgen-ray plates (Figs. 662, 665, 666) and in the *x*-rays (Figs. 664, 669–671).

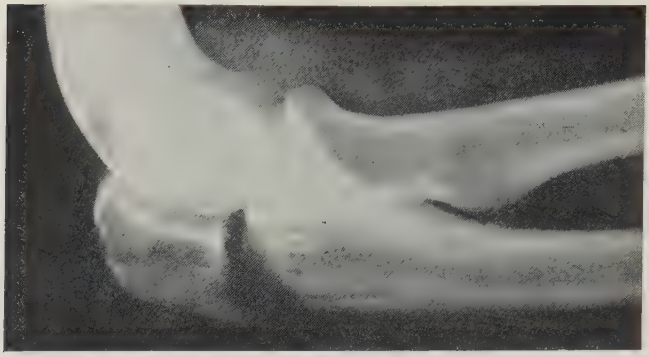

Fig. 664.—Roentgenogram of complete fracture of the olecranon process: Opening the elbow-joint (Arial George).

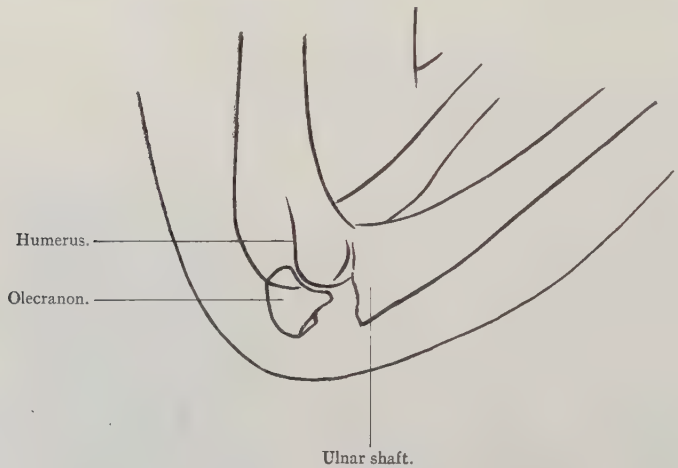

Fig. 665.—Fracture of olecranon: Separation of fragments upon flexing forearm (*x*-ray tracing).

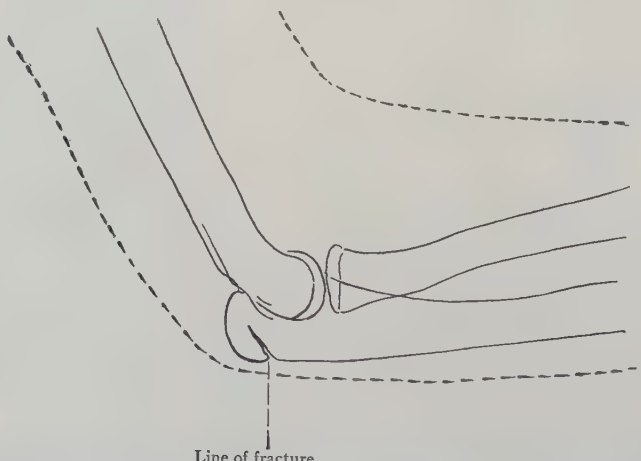

Fig 666.—Fracture of olecranon at about the epiphyseal line, without opening the elbow-joint (Massachusetts General Hospital, 1172. *x*-Ray tracing).

Symptoms.—Inability forcibly to extend the forearm, pain at the seat of fracture, and deformity, provided the fragment is separated from the shaft of the ulna. A depression marks the separation. Very great separation of the fragments is not often present. The interval between the fragments depends upon three conditions: The extent of the fascial lacer-

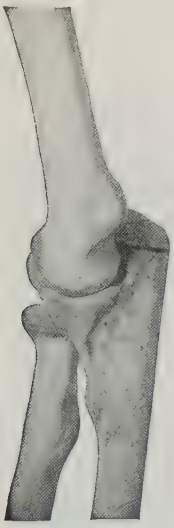

Fig. 667.—Fracture of tip of olecranon. No displacement of fragment in extended position of forearm.

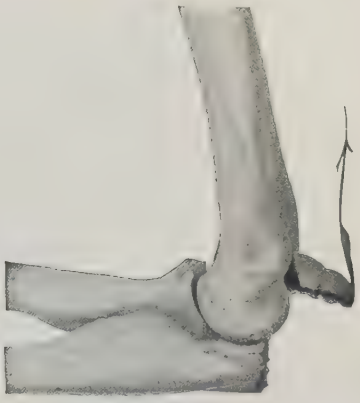

Fig. 668.—Fracture of olecranon. Note separation of fragments in flexed position of forearm.

ation—if the laceration is moderate in extent, the interval between the fragments will be slight; if the laceration is extensive, the interval between the fragments may be great; the position of the arm, whether flexed or extended

Fig. 669.—Common fracture of olecranon. Note situation and direction of fracture.

—if flexed, the separation will be greater than if extended (Figs. 667, 668); the amount of synovial fluid and blood in the joint—the greater the amount of fluid, the greater will be the separation of the fragments. The mobility of the fragments of the olecranon is determined by grasping the olecranon

firmly and attempting lateral motion (see Fig. 438). Crepitus may thus be elicited. The general swelling about the elbow will be considerable if the traumatism was severe. There exists a traumatic synovitis of the elbow-joint.

Treatment.—If there is considerable swelling of the elbow, and if the arm is large and muscular, it is not wise to rest the arm for a few days upon

Fig. 670.—Fracture of the shaft of the ulna extending backward into the joint. An unusual type of ulnar fracture.

an internal right-angle splint before putting it up permanently. The swelling will disappear most rapidly after reduction of the fragment. If there is little or no separation of the fragments in the right-angle position, the arm may be kept at a right angle. This is doubtless the most comfortable position,

Fig. 671.—A comminuted fracture of the olecranon. A rather uncommon type of fracture.

and, under these conditions, certainly is effective. If there is too great separation for the use of the right-angle position ($\frac{1}{2}$ inch or more), the arm should be extended and this position maintained by a long internal splint (Fig. 672). This splint, made of splint wood, should be the width of the arm, and should reach from the anterior axillary margin to the tips of the fingers.

This is well padded with sheet wadding at the bend of the elbow (Fig. 673). The contiguous skin surfaces of the fingers are protected from chafing by strips of gauze or compress cloth placed between them, and a pad is put in the palm for comfort (Fig. 674). The splint is held in position by four straps of adhesive plaster, one placed at either end of the splint and one above and below the elbow-joint. The upper or loose fragment is pushed down toward the shaft of the ulna, and held in place by a strap of adhesive plaster carried around the upper side of the olecranon fragment and fastened to the

Fig. 672.—Fracture of the olecranon. Arm in extension. Long anterior splint. Note pad and strap above olecranon fragment; pad in palm of hand.

splint lower down. Sheet wadding and gauze roller bandages applied from the fingers to the axilla afford comfort and prevent undue swelling of the hand. Should the separation be so great that reduction of the fragment is unsatisfactory, an incision and suture should be made (see Fig. 677).

Treatment if the Fracture is Open: The wound should, if necessary, be enlarged to permit of easy inspection of the joint surface. The joint should be thoroughly irrigated with boiled water. The wound of the soft parts, enlarged if necessary, should be débrided, very thoroughly cleansed by scrubbing with gauze wet in ether and alcohol, 70 per cent., and then the fragment of the olecranon sutured to the shaft.

The After-care.—If the arm has been put up temporarily at a right angle or at an obtuse angle to await the subsidence of the swelling, which will be

Fig. 673.—Fracture of olecranon. Arm in extension. Note upper and lower straps; oblique olecranon strap; padding of splint.

Fig. 674.—Fracture of olecranon. Bandage applied to the same case as shown in Figs. 672, 673. Note protection of fingers from chafing by compress cloth and bandaging of hand.

Fig. 675.—Showing active motion possible on the tenth day after operation for fracture of the olecranon (Hawley's case).

rarely necessary, gentle massage and firm bandaging of the arm, twice daily, until the swelling subsides sufficiently for a more permanent dressing, will be of very great service. The arm should be inspected each day for the first week. Daily massage should be continued not only to the joint

Fig. 676.—Showing active motion possible following fracture of the olecranon with immediate wire suture on the tenth day after operation (Hawley's case).

region, but to the forearm and upper arm as well. The straps and bandages should be reapplied as they become too tight or are loosened by the disappearance of the swelling. After about two weeks the position of the

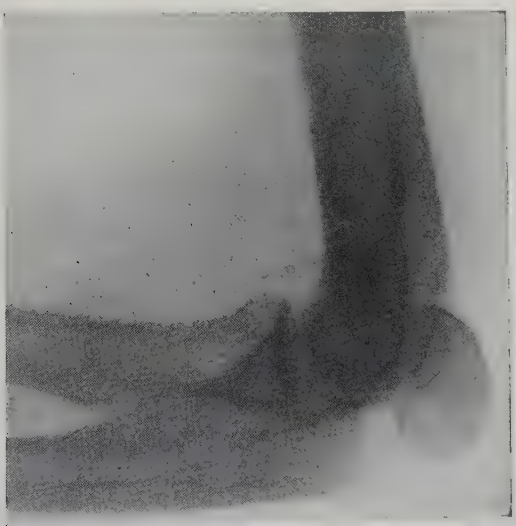

Fig. 677.—Fracture of the olecranon by a fall on the ice. *x*-Ray taken before operation (Hawley's case).

forearm may be cautiously changed. The small fragment of the olecranon should be held fixed by the fingers during the manipulation. If the arm is in the extended position, it should be gradually actively and voluntarily flexed some 5 or 10 degrees, and returned to the extended position. If the

arm is already at a right angle, it should be gradually actively extended, at first a few degrees only, and returned to the right-angle position. No pain should be experienced in the active movement. Painful passive motion is

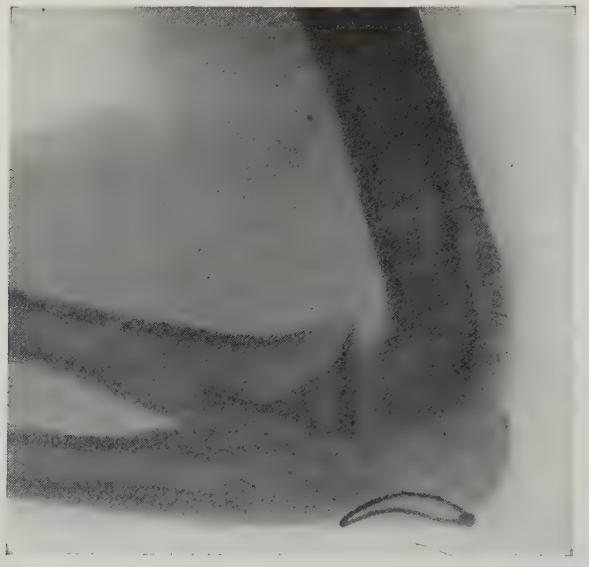

Fig. 678.—A wire mattress-suture placed so as to approximate the olecranon fragment to the shaft. Note close approximation held by suture. *x*-Ray three weeks after operation. Note rapid repair (Hawley's case).

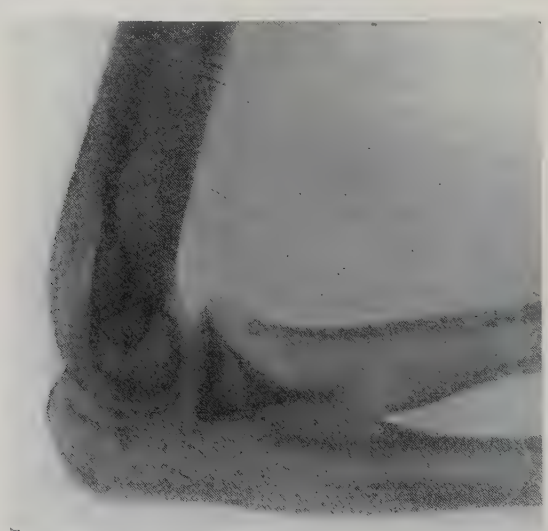

Fig. 679.—Fracture of olecranon. *x*-Ray after removal of wire suture three weeks after operation. Note complete and practically perfect approximation and repair of the fracture (Hawley's case).

harmful. After a few days of these gentle active motions it will be wise to alter the angle of the splint so that the arm may rest in the changed position permanently. After about four or five weeks all splints should be omitted.

Figs 680, 681.—Fracture of the olecranon. Wire suture used. Active motion after six weeks. Photographs taken at the factory after return of patient to work (Hawley's case).

Fig. 682.—Compound fracture of the olecranon process and the ulna shaft. Note method of suspending forearm—Carrel-Dakin treatment in use. Note container, delivery tubes; partly covered wound. Note that the position of the upper extremity is not materially disturbed or altered by this method of suspension when the dressing is changed. See Fig. 683. (Leland.)

A bandage should be worn after the removal of the splints to afford a feeling of support to the elbow.

Union of the fragments usually takes place in from three to four weeks. After six weeks to three months the movements of the elbow-joint should be normal. There may remain as a permanent condition slight limitation of extension. The functional usefulness of the elbow depends more upon

Fig. 683.—Same as Fig. 682. Compound fracture of the olecranon process and the ulna shaft. Note method of suspension and moderate traction in forearm; grip for hand; suspension of upper arm; use of Carrel-Dakin treatment. Note container and rubber delivery tube and bulky dressing outside the inner dressing (Leland).

the approximation of the fragments and less upon the kind of union between them. Following non-operative treatment the union between the fragments is more often ligamentous than bony. The short fibrous union if of good width—*i. e.*, if it covers the whole of the broken surface—may be as efficient as a bony union. A ligamentous union accompanied by great disability in the functional usefulness of the arm should be excised and the bony fragment sutured to the shaft. Suturing of the periosteum and

fibrous tissue about the fragments may prove almost as satisfactory in certain cases as suturing the bone with wire.

Close approximation of the fragment to the ulna shaft should be attempted. Bony union is highly desirable and will be secured just in proportion as the approximation is complete. Hawley reports splendid results by wire suture and early active motion (see Figs. 676, 677, 681).

Operative Treatment.—The ideal result will be bony union, a perfect joint surface, perfect motion in flexion and extension. I believe that the likelihood of attaining this ideal result will be best approached if the operative treatment by suture is used. Operation should be done in cases of wide separation where no contraindications to operation exist.

COLLES' FRACTURE

A fracture of the lower end of the radius within about three-quarters to one inch of the articular surface is common in adults and is unusual in childhood. A fall upon the outstretched and extended hand is the most frequent cause. With the introduction of the gasoline engine a new cause for fracture exists. The starting of a gasoline engine by turning a handle connected with the fly-wheel may be the occasion of a violent twist of the hand backward. The force causes a clean, transverse fracture of the lower end of the radius, close to the joint, and without impaction.

Fig. 684.—Method of examination in a case of injury to the lower end of the radius. Grasping the radius above and below the probable seat of fracture.

Anatomy.—In a case of traumatism to the wrist the normal anatomic relations should be studied upon the uninjured wrist, and then a careful examination made of the injury. The normal wrist should be looked at from the front and back and from each side with the hand supinated. Anteriorly, the base of the thenar eminence is lower than that of the hypothenar eminence. Posteriorly, on the inner side, the styloid process of the ulna is visible with the marked depression below it. Laterally, on the radial side, is seen the curve backward on the anterior surface of the radius where the base of the styloid process of the radius joins the shaft. Laterally, upon the ulnar side, are seen not only the styloid of the ulna and its associated depression, but the hollow above the prominence of the hypothenar eminence.

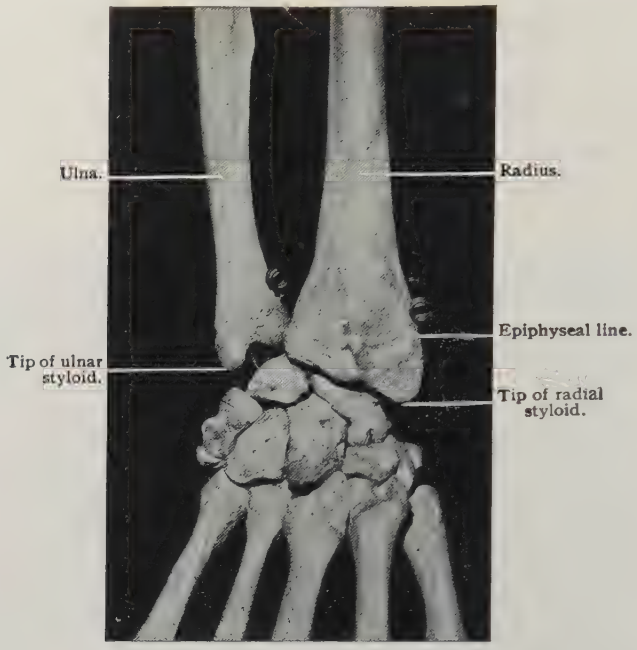

Fig. 684A.—Supination. Compare with Fig. 684C. Note the relative positions of styloid processes of ulna and radius. The two styloids are palpated in this position.

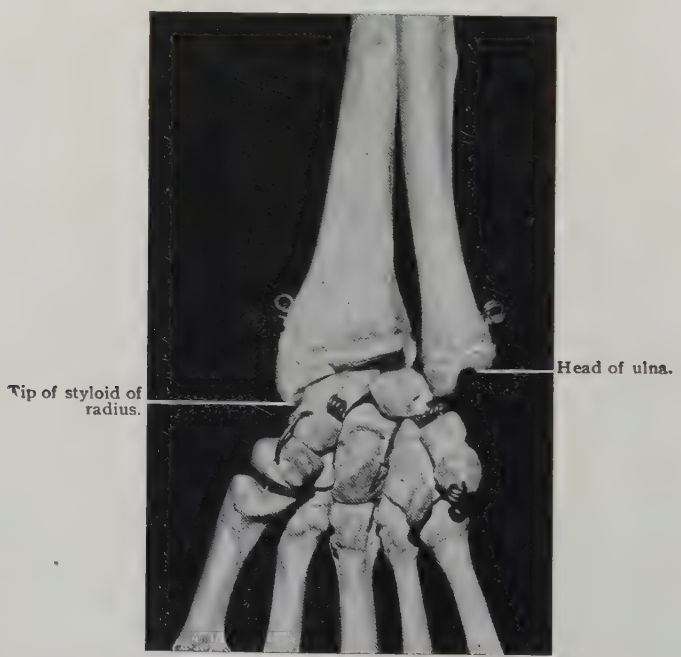

Fig. 684B.—Pronation. Compare Fig. 684D. Note that palpating fingers feel styloid of radius and *head* of ulna.

The normal wrist should be felt with the hand both in supination and pronation. With the hand supinated (see Figs. 684A, 684C) the tip of the styloid

Fig. 684C.—Method of examination of wrist. Note supination of forearm; position of examining hands and fingers; palpation of the styloid process of the radius and the head of the ulna. The radial styloid is seen to be lower than the head of the ulna. Compare with Fig. 684A.

Fig. 684D.—Method of examination of wrist Note pronation of forearm; position of examining hands and fingers; palpation of styloid processes of radius and ulna. The styloid of the radius is lower than the styloid of the ulna. Compare with Fig. 684B.

process of the radius is found to be lower (nearer the hand) than the head of the ulna. With the hand in pronation (see Figs. 684B, 684D) the tip of the styloid process of the radius is found to be a little lower (nearer the hand) than

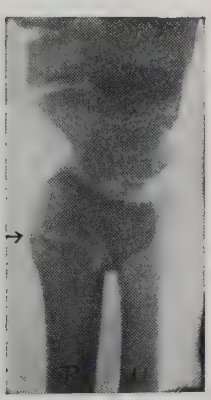

Fig. 685.—A "reversed Colles'" fracture. Arrow points to the site of fracture. Note that the displacement of the upper end of the lower fragment is backward.

Fig. 686.—A Colles' fracture. Injury to the styloid process of the ulna. Arrows point to sites of fracture. Note the comminution of the radius.

the tip of the styloid process of the ulna. To ascertain the relative position of the styloid processes the injured wrist should be grasped by the two hands and the styloids felt by the tips of the forefingers. The styloid process of

Fig. 687.—Colles' fracture. Characteristic appearance. Note backward displacement of the hand and wrist. Palmar prominence.

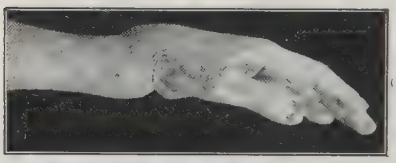

Fig. 688.—Colles' fracture, radial side. Marked crease at base of thumb. Dorsal and palmar prominences.

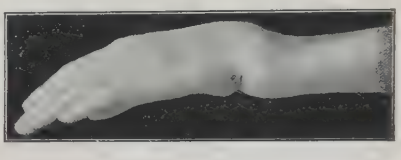

Fig. 689.—Colles' fracture, ulnar side. Absence of ulna on the dorsum of the wrist; presence anteriorly. Marked crease in front of displaced ulna. Dorsal prominence marked.

Fig. 690.—Colles' fracture, anterior bulging of flexor tendons; absence of dorsal prominence of head of ulna.

Fig. 691.—Colles' fracture. The dorsal prominence is not uncommonly seen after recovery from fracture of the radius when the displaced bones have been but partially reduced. Slight lateral deformity.

Fig. 692.—Colles' fracture. Hand carried to radial side. Prominent ulna anteriorly. Thenar eminence lower than normal.

the radius and the shaft immediately above it should be carefully palpated to determine the extreme thinness of the bone above the thick styloid process (Fig. 684). The width of the wrist between the styloid processes should be measured by means of a tape or, better, by a pair of calipers.

The movements of the normal wrist and forearm should be carefully observed. Pronation and supination of the forearm and flexion, extension, abduction, and adduction of the hand should be carefully performed. These simple observations quickly made upon the normal wrist enable one to establish a standard for comparison with the injured wrist. In every case in which there is a question of fracture the examination should be made by means of an anesthetic. If for sufficient reason complete anesthesia is contraindicated, primary anesthesia will prove to be sufficient. In the larger proportion of cases of Colles' fracture primary anesthesia will be satisfactory for both the examination and the first dressing of the fracture.

Symptoms.—In Colles' fracture the wrist appears unnatural. The thenar eminence of the thumb is higher, nearer to the wrist than usual, as compared with the hypothenar eminence (Fig. 692). Anteroposterior and

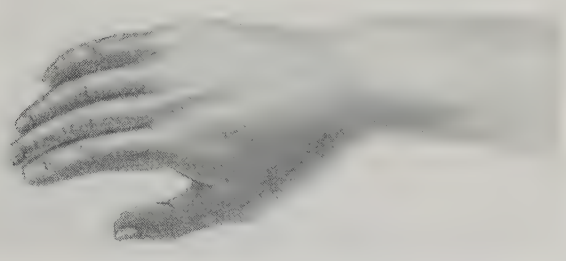

Fig. 693.—Note deviation of the hand to the radial side, thumb side, following the impaction of a Colles' fracture (after Davis-Peotti).

lateral deformities are apparent to a greater or less degree. It is said that at times an anterior displacement of the lower fragment occurs, the reverse of the ordinary displacement. It is unusual (see Fig. 685).

The anteroposterior deformity is caused by the projection of the lower end of the upper fragment into the palmar surface of the wrist, pushing the flexor tendons forward (see Figs. 690, 694), and by the projection of the upper end of the lower fragment toward the dorsal surface of the wrist, pushing the extensor tendons backward. Impaction of the radial fragments may be another factor in the production of the deformity. This deformity is spoken of by the older writers as the silver-fork deformity. The reason is obvious (see Figs. 687–693). The lower anterior radial arch is lost.

The lateral deformity (see Figs. 692, 693) is caused by several factors: the impaction of the radial fracture, lateral displacement of the lower fragment, and rupture of the inferior radio-ulnar ligaments. The wrist is widened.

Between the radius and ulna at the inferior radio-ulnar joint is the triangular ligament holding the two bones together. The upper surface of this

ligament forms part of the inferior radio-ulnar joint. The lower or under surface of this ligament forms part of the wrist-joint.

When the lower end of the radius is drawn upward, the ulna being intact is displaced, apparently at least, downward. This ruptures the in-

Fig. 694.—Note the displacement of the fragments causing the typical silver-fork deformity. The distal fragment is displaced backward, the lower end of the proximal fragment is displaced forward (after Davis-Peotti).

ferior radio-ulnar ligament. This allows the ulna to move downward and forward, while the lower end of the radius moves upward and backward.

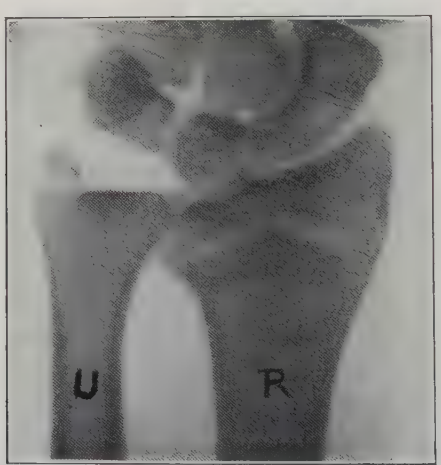

Fig. 695.—A transverse fracture of the lower end of the radius, with a crack into the joint and fracture of the styloid process of the ulna. Little displacement. See a T-fracture into wrist-joint.

Hence appears the prominence of the lower end of the ulna in the flexor side of the wrist anteriorly. This disturbance of the normal relations of this important joint explains in great measure the final partial limitation of pronation and supination seen in many improperly reduced Colles' fractures

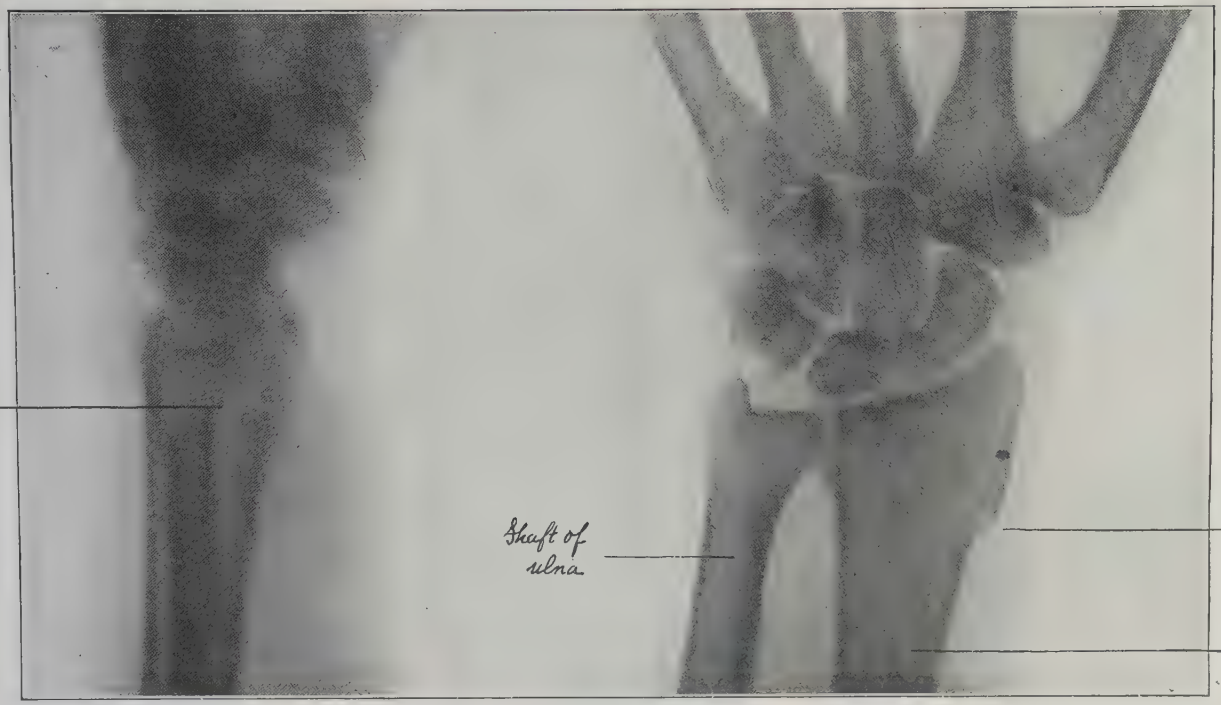

Fig. 696.—Same as Fig. 697. Lateral view.

Fig. 697.—Transverse fracture of the lower end of the radius without much displacement. Anteroposterior view.

Fig. 698.—Comminuted fracture of the lower end of the radius. The fracture could be reduced and held reduced with difficulty, as a fresh fracture. Manipulation after about ten days would result in good reposition of the fragments after granulation tissue has formed (Dodd).

Fig. 699.—Lateral view of Fig. 698.

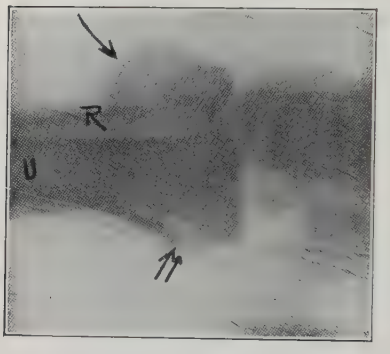

Fig. 700.—Lateral view of Fig. 703. Note the backward displacement of the lower fragment. Arrow points to lower fragment Double arrows point to the sharp lower end of the upper fragment.

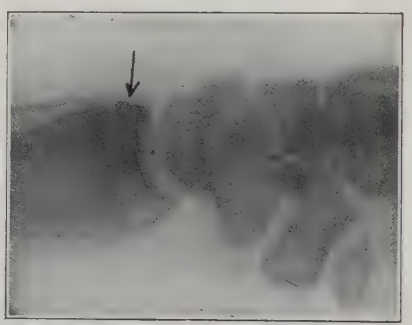

Fig. 701.—A starting of the lower radial epiphysis. No great displacement. The arrow points to the epiphysis. Note the rotation backward of the lower epiphysis in its transverse diameter.

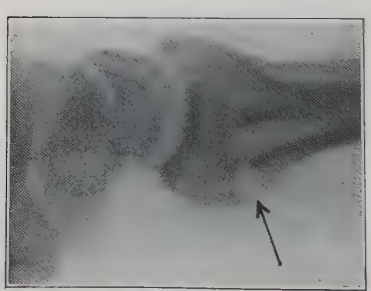

Fig. 702.—Fracture of the lower end of the radius with displacement of both bones toward the palmar surface. Arrow points to the fracture.

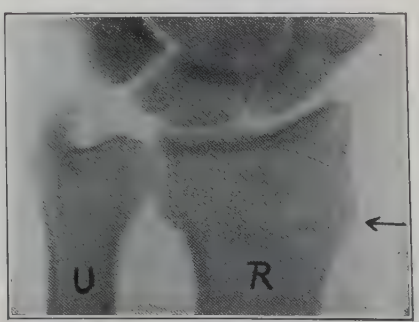

Fig. 703.—A transverse fracture of the radius above the level of the epiphyseal line. Note the impaction. Arrow points to fracture.

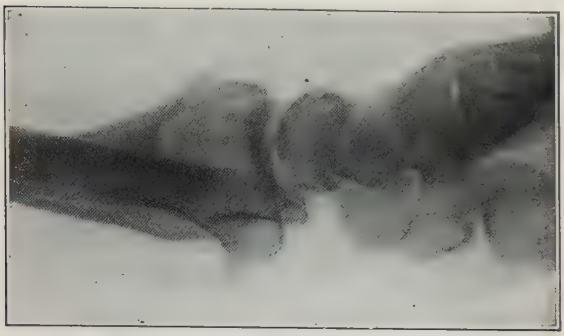

Fig. 704.—Fracture of the lower end of the radius, lateral view. Note impaction, deformity, and relative position of ulnar styloid and head.

Fig. 705.—Fracture of the lower end of the radius, anteroposterior view. Note impaction; displacement of the hand to the radial side. Note prominence of ulna.

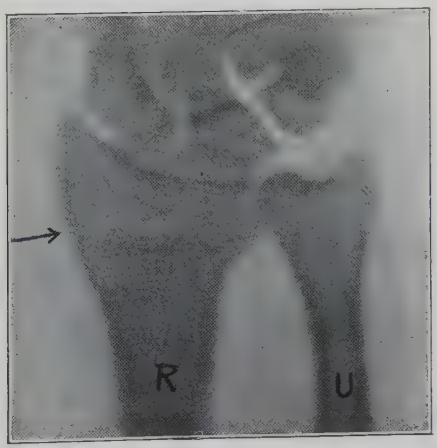

Fig. 706.—Transverse fracture of the lower end of the radius. Compare Fig. 703. Arrow marks fracture.

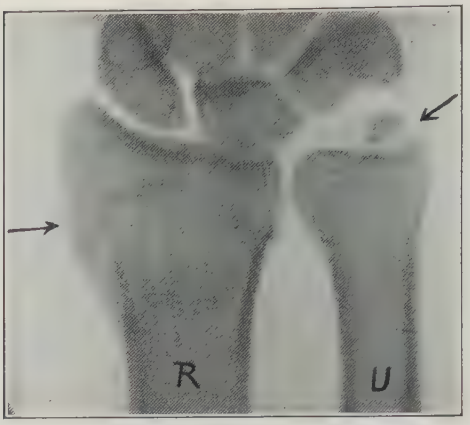

Fig. 707.—A comminuted slightly impacted fracture of the lower end of the radius and fracture of the styloid of the ulna. Arrows point to seats of fracture.

Fig. 708.—Lateral view of Fig. 706. Note the thickening due to impaction of the radius. Note also the beginning backward displacement of the lower fragment. Arrow points to fragment.

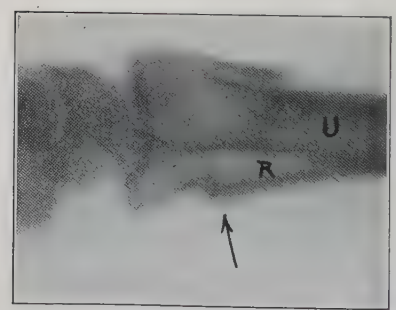

Fig. 709.—A lateral view of the fracture of the lower end of the radius. Note the characteristic backward displacement of the lower fragment and the forward displacement of the lower end of the upper fragment. Arrow points to the latter.

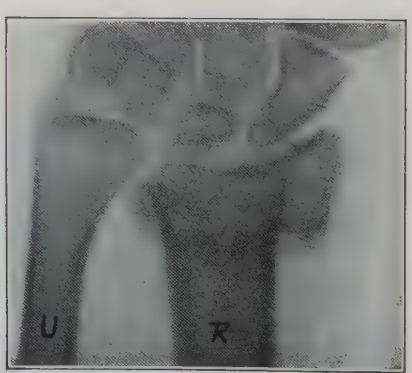

Fig. 710.—An impacted fracture of the lower end of the radius. Note the line of the cortical shaft and the upward displacement of the lower fragment.

The abduction of the whole hand (see Fig. 692), the prominence laterally of the lower end of the ulna (see Fig. 698), the disappearance of the ulnar

Fig. 711.—Longitudinal fracture of the inner side of the lower end of the radius into the joint. The arrow points to the line of fracture. The ulnar styloid is fractured.

head from the dorsum of the wrist, are to be noted. Because of the displacement of the radial lower fragment the normal relations are no longer

Fig. 712.—Fracture of the styloid process of the radius into the middle of the joint surface. Arrow points to the beginning of the fracture line in the process. A continuation of the arrow indicates the direction of the line of fracture. Relation of the two styloid processes is essentially normal.

maintained between the styloid processes of the radius and ulna. There is a reversal of relations. The radial styloid is higher than usual. It is on the same level with or higher than the head of the ulna.

It is possible to have present a fracture of the lower end of the radius (a Colles fracture) without any appreciable alteration in the levels of the styloid processes. The existence of the normal relations of the styloids does not preclude the presence of a fracture (see Fig. 712).

Direct pressure over the broken bones elicits pain, but crepitus is often undetected until the patient is examined with the aid of an anesthetic. A transverse ridge is sometimes present on the posterior and external surface of the radius, corresponding to the line of fracture. In certain cases of Colles' fracture the wrist may not appear very unnatural. There may be scarcely any deformity. The anterior skin lines at the wrist are inclined upward in the radial side, whereas normally they incline slightly downward (Eliason). The normal relation may be nearly preserved. If there is little displacement of the fragments, it may be difficult to determine the existence of a fracture. The lower fragment of the radius is rotated on its transverse diameter posteriorly so that the plane of the articular surface is somewhat reversed, being possibly from 10 to 20 degrees behind the perpendicular normal plane. The persistence of this backward rotation of the lower fragment may seriously impair certain wrist-joint movements. An appreciation of slight differences from the normal will, under these circumstances, prove of great value. The Roentgen ray, of course, will be of service in this connection.

Probably more than anywhere else in the forearm is it important to recognize the possible injuries when the trauma is at or about the wrist.

After injury to the wrist one must consider in the differential diagnosis—

A sprain of the wrist,
Contusion of the bones near the wrist,
Dislocation of the wrist backward.
Fracture of the shaft of one or both bones low down,
Separation of the lower radial epiphysis,
An incomplete fracture near the end of the radius,
A fracture of the styloid of the radius,
A scaphoid fracture,
A dislocation of a carpal bone,
Tenosynovitis of the extensor tendons near the lower end of the radius, especially of those tendons over the styloid process of the radius.

A Sprain of the Wrist is rather unusual. There very often exists in so-called sprains a definite anatomical lesion of bone. The deformity due to the distention of the synovial sac with fluid is conspicuous over the back of the wrist-joint and, therefore, near the hand. There is tenderness upon pressure over the synovial membrane anteroposteriorly. There is little or no tenderness over the radius upon deep pressure. There is an absence of the positive signs of fracture. It is not an uncommon experience to find an injury to the lower end of the radius presenting no positive fracture signs, which is proved by the Roentgen ray to be a break of the lower end of the radius. Many of these obscure lesions are passed over as sprains of the wrist. Any injury to the wrist, no matter how trivial, should be regarded with suspicion until there is absolute proof that fracture is absent.

A Contusion of One or Both Bones Near the Wrist-joint: Tenderness is localized. Fracture signs are all absent. The Roentgen ray will assist in determining this diagnosis.

Dislocation of the Wrist backward is rare. The posterior prominence is lower down on the wrist than in Colles' fracture. The upper surface of the

Fig. 713.—Comminuted fracture of the lower end of the radius. Note the outward displacement of the styloid of the radius and the comminution of the articular surface of the lower end of the radius.

displaced carpus can be felt. The relation of the two styloids is preserved. The deformity disappears and does not tend to reappear when traction is made on the hand and pressure is made over the dorsal prominence.

Fig. 714.—Comminuted fracture of the lower articular end of the radius. See Fig. 715. A T-fracture into wrist-joint.

Fracture of the Shaft of one or both bones low down may simulate the anteroposterior deformity of Colles' fracture, but an absence of other positive signs is important. The Roentgen ray determines the exact seat of the

lesion. Abnormal mobility and crepitus are readily obtained without the administration of an anesthetic.

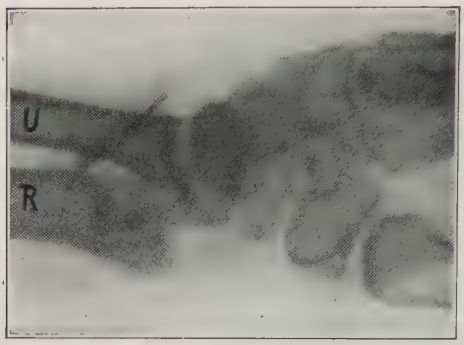

Fig. 715.—Lateral view of Fig. 714. Note the displacement of the lower fragment backward, carrying with it the hand.

Fig. 716.—Lateral view of a Colles fracture. Note the anterior displacement of a portion of the fracture fragments. The arrow points to the fragment.

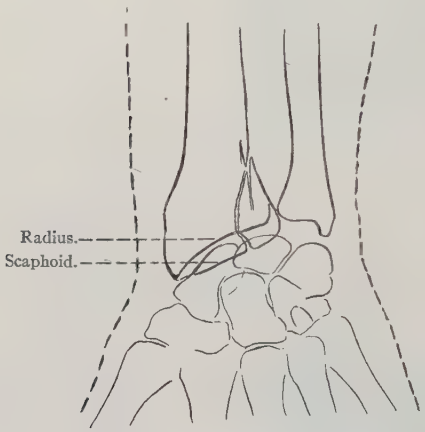

Fig. 717.—Fracture of inner edge of the radius (*x*-ray tracing).

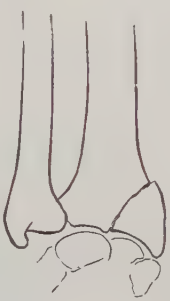

Fig. 718.—Fracture of radial styloid (Massachusetts General Hospital, 1252. *x*-Ray tracing).

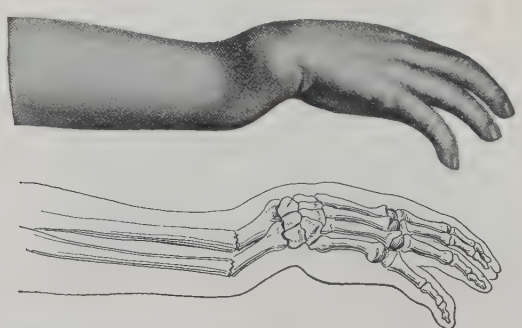

Fig. 719.—Fracture of both bones near wrist. Note deformity away from (above) wrist-joint (after Helferich).

A Separation of the Lower Epiphysis of the Radius: The lower epiphysis of the radius unites with the shaft about the twentieth year. The radius

increases in length chiefly through growth from its lower epiphysis. This lesion occurs much more commonly than has hitherto been supposed. It

Fig. 720.—Fracture of the lower end of the radius. Lateral view. Note silver-fork deformity. Deformity (above) near wrist-joint (after Helferich).

Fig. 721.—Fracture of the lower end of the radius into the wrist-joint. Fracture of the styloid of the ulna. Note comminution of lower fragment of radius.

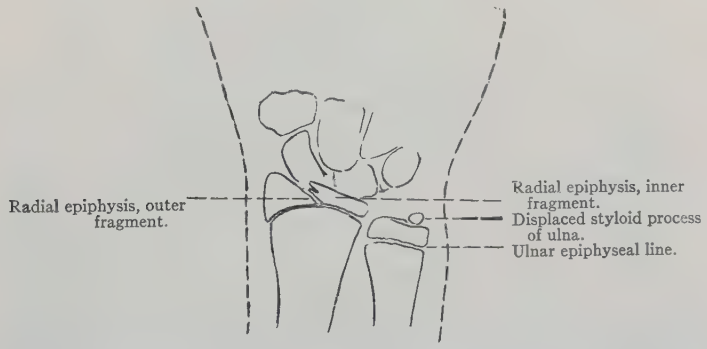
Radial epiphysis, outer fragment.
Radial epiphysis, inner fragment.
Displaced styloid process of ulna.
Ulnar epiphyseal line.

Fig. 722.—Fracture of the epiphysis of the lower end of the radius and of the styloid process of ulna (Massachusetts General Hospital, 712. *x*-Ray tracing).

is usually classed as a Colles fracture, no very careful examination being made. The displacement of the epiphysis is backward, but it is not sufficient to carry the fragment off and out of contact with the diaphysis. In

Colles' fracture the dorsal swelling is most in evidence. In a separation of the lower radial epiphysis the palmar swelling is greatest. The lateral deformity of the wrist is usually absent in epiphyseal separations. There is often less deformity than is found in most Colles' fractures, and it is nearer the hand. The crepitus is soft and cartilaginous, and easily obtained without an anesthetic. Pain is present as well as tenderness to pressure over the epiphyseal line. There is often swelling along the dorsum of the wrist corresponding to the area of detached periosteum. Union is rapid and com-

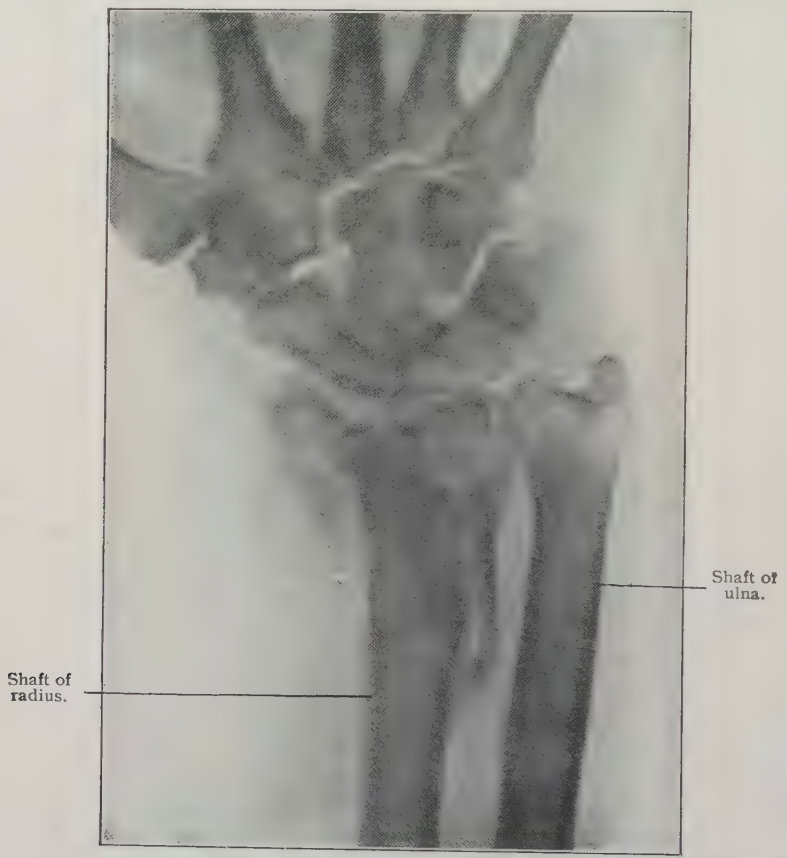

Fig. 723.—Very great comminution of lower end of the radius. Extremely difficult to mold fragments into good positions. Note abduction of hand and marked prominence of ulna.

plete. There is almost never any arrest of growth following this injury. The treatment of separation of the lower radial epiphysis is similar to that of a Colles fracture. A fracture of the lower radial epiphysis is occasionally seen; it is, however, a rare lesion (see Fig. 722).

Associated with every Colles' fracture there may be one or more of the following lesions: A fracture through the lower end of the ulna, which is rather rare. A fracture of the styloid process of the ulna, which occurs in about 50 to 60 per cent. of all cases (see Fig. 707). A rupture of the interarticular

triangular fibrocartilage (see Figs. 747, 748) at its insertion into the base of the styloid process of the ulna. This is probably quite common, and accounts

Fig. 724.—Dorsal dislocation of the wrist. Note deformity at wrist-joint, neither above nor below it (after Helferich).

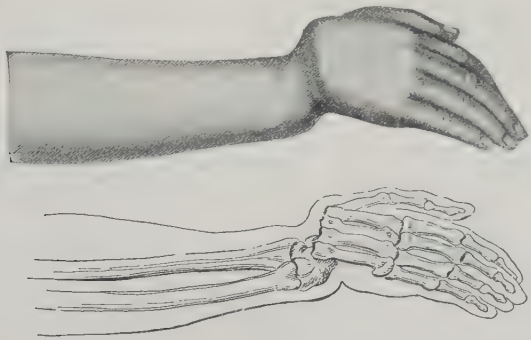

Fig. 725.—Dorsal dislocation of the hand at carpometacarpal joints. Note deformity below wrist (after Helferich).

in part for the broadening of the wrist-joint. A perforation of the skin by the lower end of either the ulna or the shaft of the radius, making an open

Fig. 726.—Reduction of Colles' fracture. Note position of hands in forcibly hyperextending the lower fragment; breaking up impaction. Disengaging the fragments.

fracture. A fracture of the scaphoid bone, although occurring often alone, is not very uncommonly associated with Colles' fracture. A sprain of the

hand, wrist, forearm, elbow, or shoulder may occur. It is wise to examine the whole upper extremity, particularly a few days after the accident, as it is at this time that sprains associated with fracture are likely to be detected.

Treatment.—The ordinary uncomplicated fracture is here under consideration. Reduction should be accomplished as soon as possible. Complete reduction cannot be made satisfactorily without the administration

Fig. 727.—Reduction of Colles' fracture. Note grasp upon forearm and the lower fragment of the radius, traction and countertraction being made; breaking up the impaction, disengaging fragments.

of an anesthetic, either to complete or partial anesthesia. Very great force is needed to accomplish satisfactory reduction of impacted fractures of the radius. It is because of the use of too little force that often a slight bony deformity remains after union has taken place.

A Method of Reduction.—Grasp with the thumbs and forefingers of the two hands the upper and lower fragments. Free the lower fragment com-

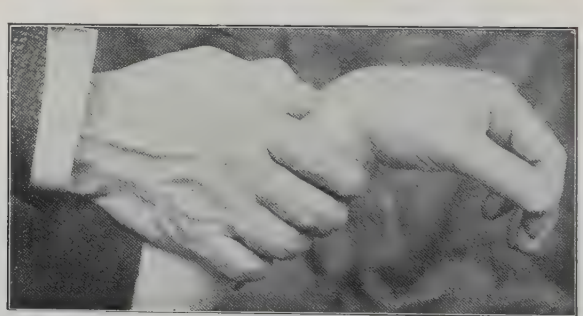

Fig. 728.—Reduction of Colles' fracture. Note position of the thumbs and fingers. Lower fragment is pushed into place, while counterpressure is made by the fingers upon the upper fragment, that is, the lower fragment is forcibly flexed.

pletely from the upper by pressure and traction backward and forward and laterally upon the lower fragment, using all the force that is needed (Figs. 726, 727). The lower fragment may then be forced into position by pressure of the two thumbs upon the dorsum of the wrist (Fig. 728).

Summary of Method of Reduction.—Disengage the two fragments of the fracture by traction on the lower fragment and by hyperextending the wrist, be sure that any existing impaction is completely broken up and freed.

Then pronate by rotating into pronation the distal radial fragment about the ulnar head as a pivot, making a lifting push backward on the ulnar head so as to correct its slump or dislocation forward.

Then flex the wrist to maintain the lower fragment in its reduced position. The flexion keeps permanent posterior ligamentous and tendinous coaptation to the replaced fracture.

Cotton's calling attention to the rotation of the radius around its longitudinal axis in extreme pronation, with the head of the ulna fixed, is a distinctly constructive contribution to the method of reduction of Colles' fracture.

When reduction is completed, the hand should be allowed to rest naturally without support to determine whether there is a recurrence of the deformity. If there is no recurrence of the deformity, the fracture may be fixed. If there is recurrence of the deformity, notice should be taken of the direction of the displacement of the lower fragment, that proper pads may be applied to hold it in position. A pad of compress cloth placed on the dorsum of the

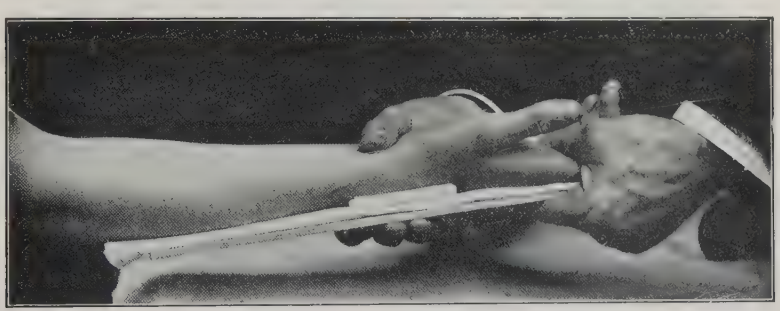

Fig. 729.—Fracture of radius near wrist. Method of applying the posterior splint and dorsal pad in displacement of lower fragment backward.

wrist over the lower fragment will easily hold it if ordinarily displaced. A knowledge of the direction of the displacement of the lower fragment will suggest the prevention of the recurrence of the deformity. The Roentgen ray is making possible a more intelligent treatment of this fracture of the radius. The bone is so nearly subcutaneous that one can take advantage of an accurate knowledge of the line or lines of fracture in attempting reduction of the malposition. Intelligently applied force can now be used in each fracture instead of the hitherto blind routine manipulation. Thus, less injury is done in setting the fracture, and better anatomic results are obtained.

It is well to restore, if possible, the prominence of the lower end of the ulna at the back of the wrist. Usually, after a Colles fracture has healed and functional usefulness exists in the wrist and hand, the ulna will be found to have slumped forward—to have disappeared from the dorsum of the wrist. This can be prevented partially at the time of setting the fracture by padding the ulna anteriorly and by *completely correcting the radial deformity* and strongly adducting the hand.

Retentive Apparatus.—The simplest splint is the best. If there is considerable swelling about the seat of fracture in a rather muscular and large arm, it is best to use the following apparatus: Two pieces of splint-wood, one for the back and the other for the front of the forearm, are provided. The back or posterior splint should extend from the heads of the metacarpal bones to a little above the middle of the forearm (see Fig. 729). At

Fig. 730.—Fracture of radius near wrist. Method of applying anterior splint and pad and of holding the two splints and arm for the application of straps. Anterior splint is cut out below the thenar eminence.

the spot where the lower end of the ulna touches the dorsal splint a piece should be cut out from the splint (Fig. 736). If this is done there will be no undue pressure forward upon the lower end of the ulna (Pool) and the likelihood of an absence of ulnar prominence upon the back of the wrist will be lessened. The front or anterior splint should extend from the heads

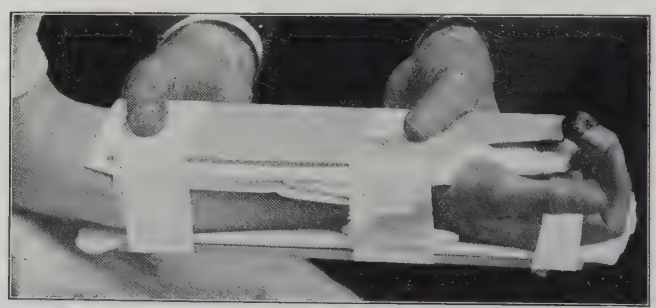

Fig. 731.—Fracture of the forearm near the wrist-joint. Anterior and posterior splints. Straps are taut. Note length of splints, the position of the three straps, and the cutting out of the anterior splint to clear the thenar eminence.

of the metacarpal bones to a little above the middle of the forearm (see Fig. 731). These splints are padded evenly and smoothly with sheet wadding, retentive pads at the seat of the fracture being used as needed. The hand and forearm are held in semipronation. The hand is adducted. The dorsal splint is applied and held in position. The anterior splint is then applied with the pads, and all are held in position by adhesive-plaster straps. The

arm and splints are covered with a bandage. Direct pressure should be avoided over the head and styloid process of the ulna posteriorly in order to minimize the disappearance of the bone from the dorsum of the wrist. A pad placed anteriorly and laterally over the lower end of the ulna is often useful in reducing the ulnar head and styloid. The adhesive-plaster straps should be snugly but loosely applied. They are intended simply to retain the splints in position (see Fig. 731). After their application, pressing the

Fig. 732.—Fracture of the forearm near the wrist-joint. Notice wrinkles in the straps. The straps are loose from the pressure of the two splints together. Thus is illustrated the fact that the straps should retain splints in position without exerting much pressure.

two splints together should show that there is considerable slack in the straps (see Fig. 732); a springiness should exist between the splints. The necessary pressure on the splints should be secured by the bandage. The fingers are allowed to be free and movable. The arm is held in a sling. The sling should be so adjusted as to receive the whole weight of the arm, the hand lying free from the upward pressure of the sling. The sling should be applied with the ends crossed in front of the neck.

At the end of the first week in most cases, in place of the two antero-posterior splints, it will be wise to use one posterior splint only and an an-

Fig. 733.—Posterior splint padded with two thicknesses of sheet wadding. Two straps. Note length of splint and position of straps.

terior pad over the seat of fracture. The posterior splint is applied evenly padded, and, if necessary, a small pad is placed over the dorsum of the lower fragment. The splint is held in place by two adhesive-plaster straps, one at the upper end of the splint around the forearm, the other around the meta-carpal bones at the lower end of the splint (see Fig. 733). The fracture should be held securely by a third strip of adhesive plaster at the seat of fracture over a compress-cloth pad, which fills up the anterior hollow of the radius

Fig. 734.—Posterior splint, three straps, and pad at the seat of fracture. Note comfortable position of forearm and hand.

Fig. 735.—Completed dressing, similar to Figs. 733, 734. The bandage is applied evenly and uniformly.

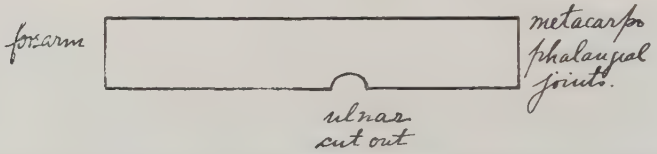

Fig. 736.—To illustrate *ulnar cut-out* on the dorsal splint for Colles' fracture of the right wrist.

Fig. 737.—Hand and fingers extended. Dorsal surface of forearm and hand practically straight and in the same plane. The anterior surface of the forearm and hand are rounded and irregular surfaces.

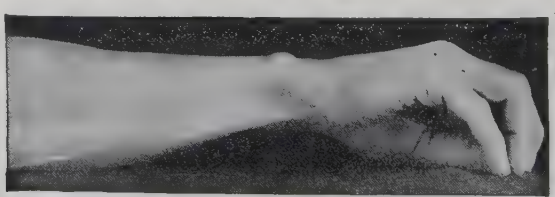

Fig. 738.—Forearm, ulnar side; partial pronation. Note *normal* prominence of head of ulna (Pool).

(see Figs. 734, 741). This pad holds the fragments securely. A roller bandage gives even compression and support to the whole arm (see Fig. 735).

The posterior surfaces of the forearm, wrist, and hand in the extended position are practically in one plane (see Fig. 737); hence, the reasonable-

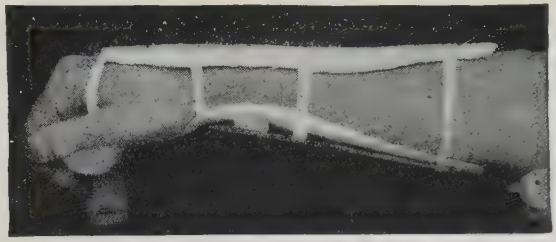

Fig. 739.—Radial side of forearm with anteroposterior plaster splints applied. Roll supporting fingers; straight wooden splint upon anterior plaster splint for greater support. Small block of wood anterior to the lower end of the radius (after Pool).

ness of the use of the posterior splint. The arm lies naturally upon it. The anterior surface only requires accurate padding. The difficulty in applying an anterior splint accurately to the forearm and wrist is rendered clear by the illustration. The front of the forearm and wrist is a rounded and

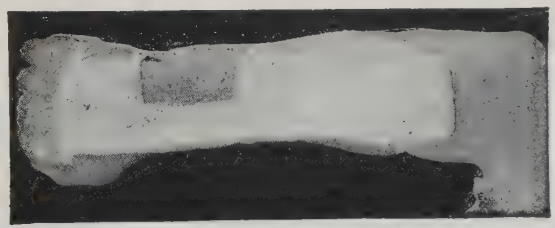

Fig. 740.—Dorsal splint of plaster of Paris showing ulnar cut-out (after Pool).

uneven surface. In order accurately to control the bone by a splint applied to the anterior surface of the forearm the padding must be applied with greater care than is ordinarily exercised. No splint is manufactured that

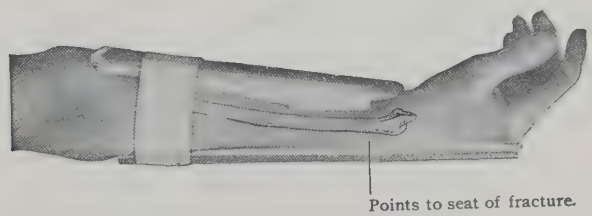

Fig 741.—Anterior and posterior splints. Note how naturally the dorsum of forearm and hand rest upon straight splint. Note pad necessary to fill the normal arch of radius. The strap at the wrist is purposely omitted so as not to obscure the bone.

fits the wrist accurately. If the surgeon depends upon manufactured and molded splints, he is in very great danger of neglecting the fracture. It is best for the surgeon to use simple splints, and to hold the fracture reduced by personally applied pads and straps.

Until the time of union the arm should always be comfortable. The patient should be seen, if convenient, within the first twenty-four hours of the application of the splint. Swelling may occur after the splints are applied, causing blueness or swelling of the fingers. The bandage may need reapplying to relieve this increase of pressure. With the subsidence of the primary swelling the bandage naturally loosens and will require tightening. It is rare that the straps and padding will need more than slight readjustment during the first week of treatment. At least every three days the pads should

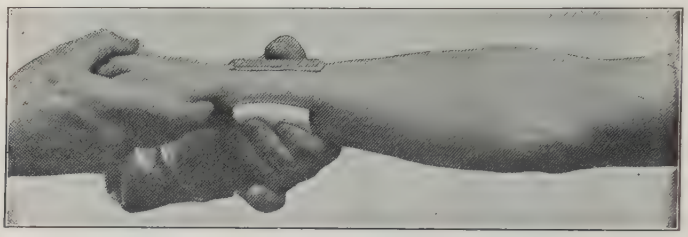

Fig. 742.—Colles' fracture. Position of short dorsal splint of wood and palmar pad of compress cloth. Note method of holding before the application of the strap.

be removed with great care, and the arm carefully inspected. The alignment of the fragments is maintained by readjustment of the pads.

Gentle massage should be instituted to the fingers, hand, wrist, and forearm during the first week. Passive and active movements of the fingers and wrist are to be made through the second week. During the second or third week it will be possible to shorten the dorsal splint and also to increase the amount of passive and active motion. At the end of

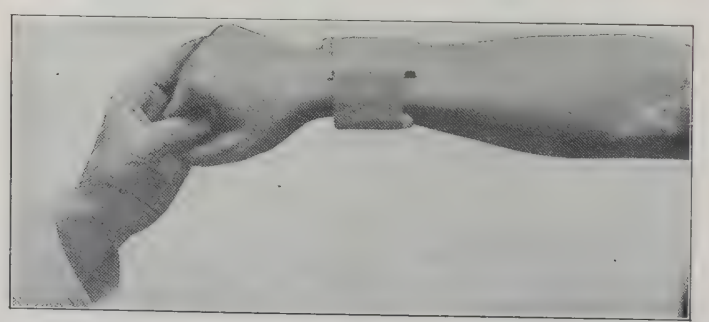

Fig. 743.—Colles' fracture. Short dorsal splint and palmar pad held in position by adhesive-plaster strap.

the second or third week the union will be found to be firm. During the third or fourth week the splint may be removed and the wrist be supported by a wooden dorsal pad (see Figs. 742, 743) 2 inches long and the width of the wrist, and by a palmar radial pad of compress cloth and strips of adhesive plaster about 2 inches wide. The middle of the plaster should come at the line of the break in the bone. After the fourth week all padding may be removed, and the wrist supported by a simple bandage. The fingers and hand may be used at this time. After the removal of the splint and

while the arm is carried in a sling great care must be exercised lest lateral deformity result through an improper adjustment of the sling (Fig. 744). The forearm should rest in the sling upon the ulnar side, and the hand, being unsupported, should be slightly adducted (Fig. 745).

Fig. 744.—Colles' fracture. Cravat sling holding wrist improperly. Hand pronated.

Fig. 745.—Colles' fracture. Cravat sling holding wrist properly. Hand semisupinated. Wrist resting upon ulnar side with hand unsupported.

The treatment of a "reversed Colles" fracture (see Fig. 685) will differ from the treatment of the ordinary fracture only in the method of reduction and in the position of the retaining pads. An anterior (palmar) pad will be needed over the lower fragment and a posterior (dorsal) pad over the shaft of the radius.

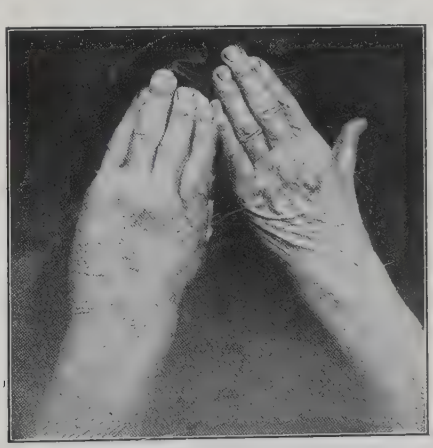

Fig. 746.—Right Colles' fracture in an old woman. Splints applied for five weeks without removal. Note deformity and flattening of hand and forearm. The fingers and wrist are stiff and swollen. Left hand is normal.

Prognosis and Result.—The swelling about the fracture in elderly people will persist longer than in the young. A functionally useful wrist-joint and hand should follow a simple uncomplicated Colles' fracture in healthy young adults. For some weeks tenderness may exist over the styloid of the ulna.

Limitation of pronation and supination may persist for some time, disappearing, after several months, more or less completely. Supination is the last movement to be recovered. Limitation of movement at the wrist and in the fingers is not incompatible with a useful wrist-joint. Bony union is rapid—within three weeks. Care must be exercised lest in the early removal of support the soft callus is molded, by the ordinary movements of the wrist and hand, into some permanent deformity.

It is not uncommon for the line of the fracture of the lower end of the radius to extend into and involve the sigmoid cavity of the radius. Thus the inferior radio-ulnar joint is involved in the fracture. This fact is of importance, as it helps to explain the limitation of motion in pronation and supination which so often exists after fracture of the lower end of the radius. Often perfect supination is the last movement to be recovered, and this may in part be explained by the involvement of the inferior radio-ulnar joint.

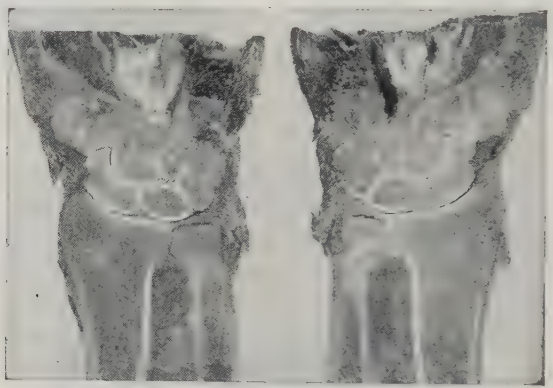

Fig. 747. Fig. 748.

Figs. 747, 748.—Longitudinal sections of the wrist-joint showing the relations of the carpal bones to the radius and ulna. Note that force applied to the hand may be partially transmitted to the ulna as well as the radius. This section illustrates also the large number of joints that may be involved following trauma to this region (Harger).

The destruction of parts of the lower fragment of the radius may have been so complete that it is impossible to restore the wrist to its normal shape, and some bony deformity will remain permanently (see Fig. 723). Bony deformity is not incompatible with a functionally useful arm. In many instances it is impossible wholly to prevent a slumping forward of the head of the ulna and its corresponding disappearance from the back of the wrist. *Complete reduction of the radial deformity* together with a frequently readjusted pad upon the palmar surface of the wrist over the slumping ulna head, the combined pronation and flexion of the wrist, together with the upward thrust on the ulnar head are the best methods for preventing the disappearance of the ulna from the dorsum of the wrist. The "ulnar cut-out" from the dorsal splint should be employed when wooden splints are used (see Fig. 736).

Some slight widening of the wrist will remain after most Colles' fractures.

Traumatic arthritis will at times appear out of a clear sky suddenly and very much complicate an otherwise simple convalescence from a perfectly replaced Colles' fracture.

The uncorrected anterior luxation of the ulnar head may be a cause of weak wrist, ulnar pain, and flattening of the ulnar prominence.

A looseness of the ulnar head, which will exist in proportion to a persistence of the radial impaction, which may become exaggerated by supination, may through repeated traumatisms injure the ulnar nerve.

The long ulna may be corrected by Darrach's subperiosteal resection of the lower inch of the ulna, leaving the styloid process, or by Berg's lengthening of the radius.

The changes in the tendon sheaths about the fracture, the periarticular adhesions that form, especially in elderly people, cause much more hindrance to recovery of function than do the bony alterations (see Fig. 746). Early and persistent massage and passive motion will prevent these changes from becoming permanently troublesome. Old people are liable to have con-

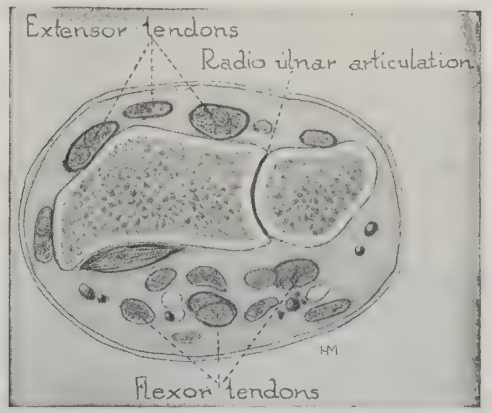

Fig. 749.—Note the position and extent of the radio-ulnar articulation which is frequently involved in fracture and which may be filled with callus. Note the close proximity of the flexor and extensor tendons and tendon sheaths. These tendons, especially the dorsolateral ones, may readily become involved in the adhesions following fracture of the lower end of the radius (Harger).

siderable difficulty in regaining the movements of the fingers on account of adhesions within and without the tendon sheaths. The continued use of the hot-air treatment is of value in restoring mobility to the wrist and fingers. The more nearly the deformity in Colles' fracture is corrected at the first setting, the milder will be the subsequent pain about the wrist.

A retentive dressing or splint that really retains the fracture reduced is satisfactory. Two wooden splints well padded, correctly used, are satisfactory.

The plaster-of-Paris splint, two strips; one for back of arm and hand and one for front of arm and hand, held in place by a plaster-of-Paris bandage or by straps, is helpful (Eliason). A plaster-of-Paris circular splint which is divided or bivalved immediately after it is dry is, perhaps, if rightly employed, the most efficacious and least troublesome splint.

CHAPTER XV

FRACTURES OF THE CARPUS, METACARPUS, AND PHALANGES

Carpus—Nomenclature—Etiology—Keinböch's disease—Metacarpus—Bennett's fracture—Phalanges—Open fracture.

FRACTURE OF THE CARPUS

The change in nomenclature is at first confusing, but the new terms for the bones of the carpus are simple, viz.:

First or Proximal Row

Navicular	Scaphoid
Lunate	Semilunar
Triangular	Cuneiform
Pisiform	Pisiform

Second or Distal Row

Greater multangular	Trapezium
Lesser multangular	Trapezoid
Capitate	Os magnum
Hamate	Unciform

Crushing injuries may fracture any of these carpal bones. The bones commonly fractured by indirect force are the scaphoid and semilunar (the navicular and lunate) of the first or proximal row.

Anatomy.—The outside of a carpal bone is covered by compact bony tissue surrounding the inside spongy, cancellous tissue. The exterior is covered by cartilage on the surfaces articulating with adjacent bones. A synovial membrane covers these articulating surfaces. The other surfaces are rough for the attachment of ligaments and tendons. Each carpal bone has a central center of ossification. Compared with fracture of the wrist (Colles') it is estimated that fractures of these two bones occur once in about ten times.

Etiology.—The cause of these scaphoid and semilunar fractures is ordinarily a fall on the outstretched hand with radial or ulnar flexion of the wrist, *i. e.*, the wrist is in forced dorsal flexion and radial or ulnar deviation. The force is transmitted through the longest and largest metacarpal bone, the third metacarpal (Hirsch). The position of the hand in receiving the blow determines largely the type of fracture produced.

There may be an *avulsion fracture* of the tuberosity of the scaphoid when the hand is in ulnar flexion (see Fig. 752).

The most common type of scaphoid fracture is the *compression fracture* resulting in a transverse break with compression of the central spongy bone. This type is caused by forced dorsal flexion of 90 degrees or more while the hand is in either ulnar or radial flexion. Fracture of the semilunar (os lunatum) is rare. It is second in frequency to fracture of the scaphoid (navicular).

Kienböch's disease (Speed) is a lesion characterized by fracture of the semilunar bone, usually comminuted, and followed by absorption of the frag-

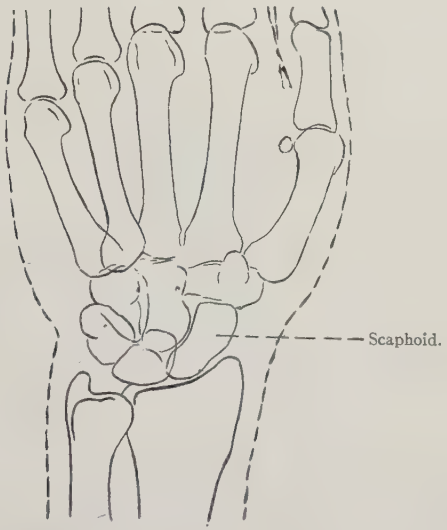

Fig. 750.—Normal wrist (*x*-ray tracing).

ments. Müller recognizes three forms according to their etiology: (1) The anatomical form due to anatomical anomalous pressure lines; (2) the occupational form due to repeated minimal traumata; (3) the traumatic form due

Fig. 751.—Typical edema following a recent fracture of the scaphoid of the wrist, line points to swelling (after Todd, British Journal of Surgery, vol. 9, p. 9).

to a single marked pressure insult or fracture. The diagnosis is made by the *x*-ray examination. These cases are important in connection with industrial compensation cases.

This disease may be overlooked or diagnosed wrongly as a sprain or "rheumatism." The symptoms are wrist-joint disability, local pain and tenderness, sometimes retraction of the head of the third metacarpal.

The treatment is conservative in the early stages and operative in old cases. The prognosis for complete return of function is poor (R. Goldsmith).[1]

Pathology.—Fractures of the other bones of the carpus are unusual. The trapezium has been fractured in association with a Bennett fracture (Kindl). Of course other bones of the carpus may be broken in crushes or smashes of the wrist. Following fracture the trabeculæ will be found crushed, disarranged, and the vascular supply interfered with. This part of the bone dies *en masse*.

If the fracture, as so often happens, is unrecognized, fibrous tissue forms at the seat of fracture, the bone is absorbed, a cavity appears in the center of the bone. The bone slowly becomes an aseptic foreign body. This bone retains its density, while the surrounding bones lose in density from lack of use. The injured bone shows in the Roentgen-ray picture as a dense white shadow.

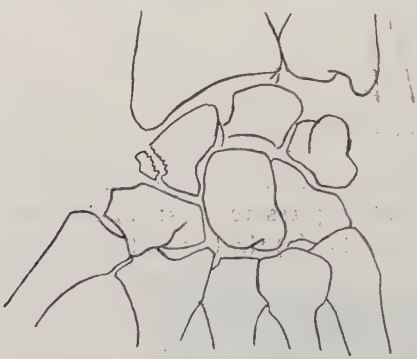

Fig. 752.—Fracture of the tip of the scaphoid, rather unusual (Arial George).

This central cavity is very constantly found in ununited scaphoid fractures as early as six weeks after fracture, particularly if they are not immobilized in treatment.

These changes in the scaphoid are analogous to those occurring in the body of a vertebra after trauma—Kummel's disease (Speed). Hirsch has described the death of the cancellous bone following fracture. The sequence of events is: fracture, death of bone, absorption of bone, cavity formation, foreign body causing a certain irritation of surrounding tissues.

Symptoms.—Fracture of the scaphoid will be attended by painful motions of the wrist, restriction of extension, an impaired hand grasp, some swelling on the radial side of wrist, and especially a fulness of the "anatomical snuff-box" a slight late ecchymosis on the radial side, tenderness on deep pressure in the "snuff-box," the "percussion test" positive, *i. e.*, tapping on the middle metacarpal head with fingers flexed and hand in radial flexion will cause pain in the scaphoid region; in ulnar flexion of the hand no such pain will be elicited; forced passive motion will be deeply painful.

In neglected and unrecognized fracture of the scaphoid the picture is a sad and disabling one, viz.: a failing hand grip, a weakness of the wrist, a constant ache in the wrist. All motions are restricted. Use of the wrist and all extreme movements increase the symptoms. Rest will relieve these symptoms. A stiffness persists. There is muscle atrophy of the hand and arm.

[1] Annals of Surgery, April, 1925.

The wrist region is thickened, especially on the radial side, the snuff-box hollow is permanently obliterated. The individual is handicapped in the ordinary use of the wrist, hand, and arm.

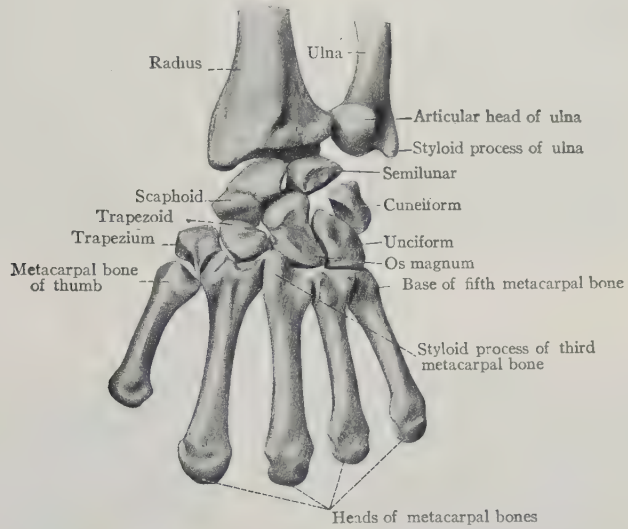

Fig. 753.—The lower ends of the bones of the forearm and the carpal and metacarpal bones in their natural positions, seen from the dorsal surface. The preparation was made from a frozen hand, whereby the relative position of the bones could be perfectly determined (Sobotta and McMurrich).

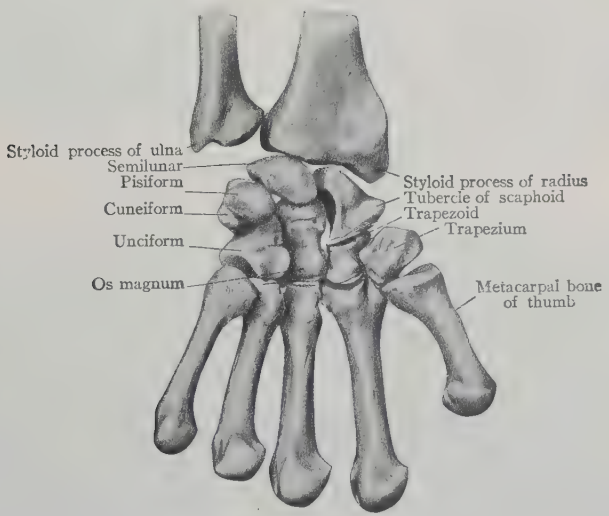

Fig. 754.—The same preparation as in the preceding figure seen from the volar surface (Sobotta and McMurrich).

The sequence of events following fracture in the scaphoid and semilunar bones places them apart by themselves as reacting differently to fracture (Speed).

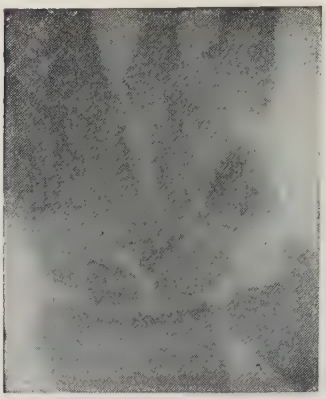

Fig. 755.—*x*-Ray of normal wrist (Codman and Chase).

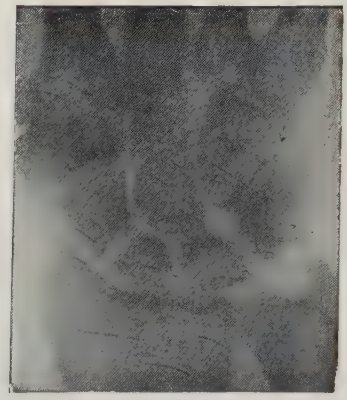

Fig. 756.—Note line of fracture through scaphoid. A five-month "sprained wrist" (Codman and Chase).

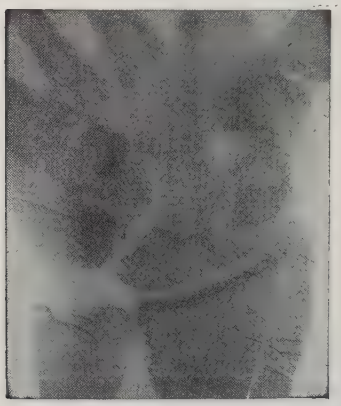

Fig. 757.—Note line of fracture of right scaphoid (Codman and Chase).

Fig. 758.—Same as Fig. 757 after removal of one fragment of scaphoid. Good ultimate recovery (Codman and Chase).

Fig. 759.—Fracture of scaphoid before operation (Codman and Chase).

Fig. 760.—Same as Fig. 759 after removal of proximal fragment of scaphoid. Good ultimate result (Codman and Chase).

A complete recovery following scaphoid or semilunar fracture is one in which after one year has elapsed there is normal painless wrist motion,

Fig. 761.—A transverse fracture of the scaphoid. Arrow points to the fracture line.

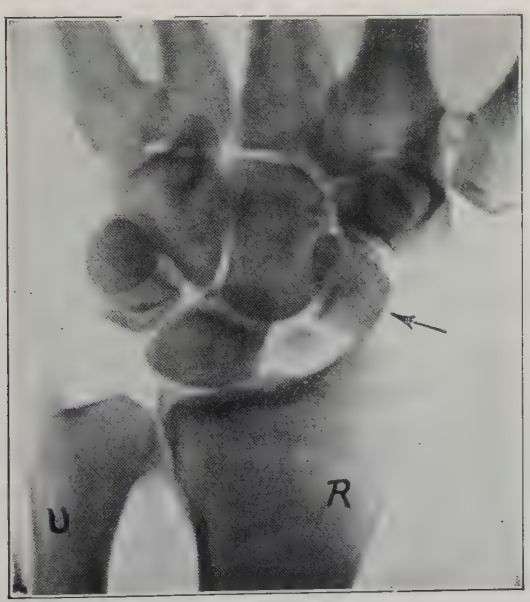

Fig. 762.—*x*-Ray taken after the removal of the inner fragment of the fractured scaphoid. Note the fragment left *in situ* and the light space formerly occupied by removed fragment. Arrow points to the fragment remaining.

no painful pressure points. A normal hand grip, no evidence of muscular atrophy, and a return to work. Adequately treated, early cases of fracture

of the scaphoid will recover well. A few will be followed by non-union and a disabling pathology. Neglected old cases in adults will remain somewhat handicapped despite treatment.

Treatment.—Recent carpal fractures should be immobilized until union takes place.

In the adult scaphoid fracture union is slow and requires from four to six weeks. In youth it requires about two weeks. The hand should be placed between the extended and flexed position, the most relaxed position possible. This position should be maintained about six weeks. The radial flexion of wrist will approximate the fragments of the fractured scaphoid most closely and materially aid the reparative process.

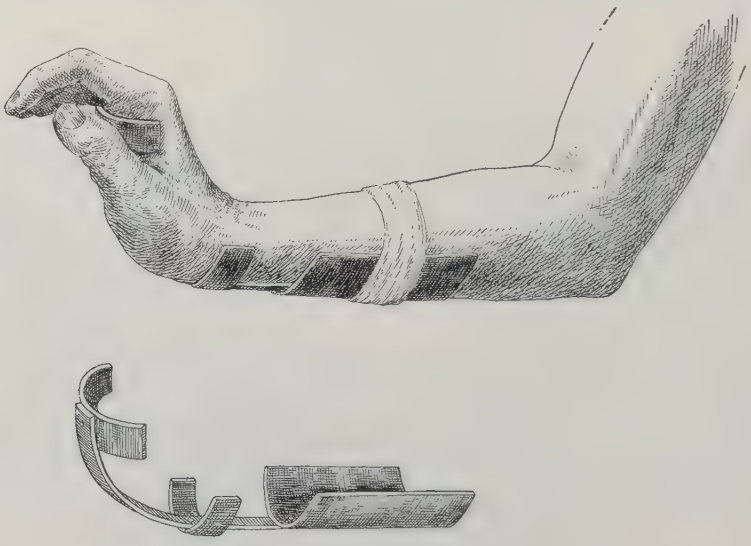

Fig. 763.—Jones' cock-up splint for drop-wrist. This splint, at least in the early stages of musculospiral paralysis, should be supplemented by splinting to prevent flexion of the fingers. It is applicable to the treatment of some fractures of the carpus and metacarpals if the transverse palmar piece is replaced by a hemisphere, with its convexity toward the palm (Blake).

In old scaphoid and carpal fractures removal of the offending bone is indicated. In all comminuted scaphoid fractures the best initial treatment will be immediate operative removal.

In youth extirpation should be reserved for employment after non-operative measures fail. Rarely will it be necessary to remove the fractured scaphoid in youth. Every fracture dislocation of a carpal bone should be immediately removed.

In scaphoid fracture in which operative removal seems indicated the whole bone should be removed. If only a portion is removed the remaining part becomes of no value as support and may act as a foreign body.

Improvement after operative removal is necessarily slow, requiring from three to six months to a year to recover the full maximum usefulness of the wrist that is to be finally secured.

If operative treatment is refused, the disabling symptoms are liable to increase. New bone will form at and around the fracture site, and after five or seven years of local invalidism, stiffness and pain at the wrist, there will be a permanent ankylosis, a loss of hand power and finger power, and atrophy of the arm from disuse.

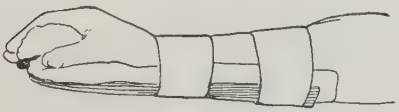

Fig. 764.—Long plaster cock-up splint holding the hand in the position of grasp, as desirable in fracture of the carpal scaphoid.

Fig. 765.—Plaster cock-up splint employed in certain cases of injury about the wrist.

(M. G. H. Conference.)

The stiffness remaining after the six weeks' immobilization in recent fractures can ordinarily be overcome in time by heat, massage, and active movements. This stiffness is not due to unremovable causes like the stiffness associated with neglected cases of fracture.

Forced passive motion with or without a general anesthetic is to be avoided as productive of great harm.

Operative Technic of Approach to Carpal Bones.

Codman's method of taking an *x*-ray of the scaphoid:

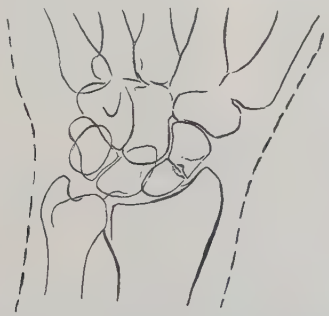

Fig. 766.—Fracture of the scaphoid. The two fragments are seen near the styloid of the radius (*x*-ray tracing) (Balch).

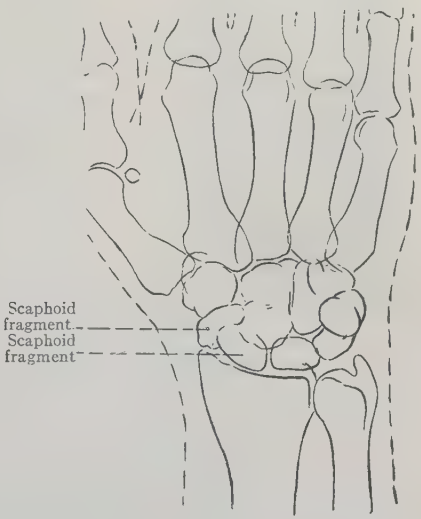

Fig. 767.—Fracture of the scaphoid (*x*-ray tracing).

A practical way to obtain a good picture of the scaphoid is to place the two wrists of the patient in adduction, and to place the tube in a position over the midline between the two hands, as far forward as the level of the knuckles.

Another point which it is well to bear in mind in making the diagnosis of fracture of the scaphoid is the existence of two more or less prominent bony ridges on the neck of the scaphoid bone which bound the edges of the articular surfaces. These ridges in some cases are very prominent, and

as the neck of bone between these two ridges is the thinnest portion of the bone, it is apt to give the appearance of a fracture unless the *x*-ray is good enough to show the detail definitely. If the *x*-ray picture is taken correctly, and a good view of the bone in its long axis obtained, a positive diagnosis can readily be made, for not only can the line of fracture be seen, but often the exact region of the interruption to the trabecular structure of the bone (Codman).

FRACTURE OF THE METACARPAL BONES

The third and fourth metacarpal bones are the ones most commonly broken. The fracture is due to a blow upon the knuckles.

Symptoms.—The deformity is characteristic. The very considerable swelling often obscures the outline of the bones, but palpation detects the lower end of the upper fragment in the dorsum of the hand, while the upper

Fig. 768.—Fracture of the base of the metacarpal bone of the thumb. Rather oblique, with considerable displacement of thumb toward the wrist.

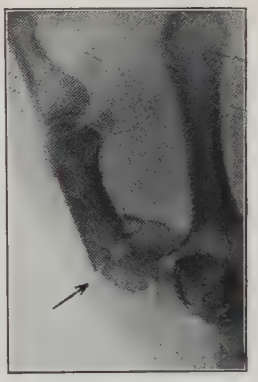

Fig. 769.—Fracture of the base of the metacarpal bone of the thumb. Note the bowing of the fragments backward.

Fig. 770.—"Stave" fracture of the thumb. Note joint involved. Note displacement of shaft of thumb metacarpal.

end of the lower fragment is sometimes felt in the palm of the hand. This deformity is characterized by a loss from a line of the knuckles of that knuckle corresponding to the fractured metacarpal (see Figs. 773, 774). Pain and crepitus are present. The hand cannot be closed tightly on account of the swelling and pain.

To obtain crepitus easily and to assist in reducing the fracture it is best to grasp the finger corresponding to the fractured metacarpal with the whole right hand, steadying the injured metacarpus with the left hand, and then to make steady and continuous traction (see Fig. 775). The distal fragment is so short and movable that unless this method is used to steady the fragment it will be difficult to determine crepitus and to reduce the fracture. This fracture heals readily. Occasionally, however, a suppurative

process may complicate recovery even when the fracture is not an open one.

Bennett's fracture, commonly designated "stave" of the thumb and "punch fracture," should be mentioned here. The fracture is usually caused

Fig. 771.—Separation of the epiphysis of the first metacarpal bone. Boy fourteen years of age (Coues).

by a blow on the end of the thumb. The right thumb is oftenest involved. The bone is driven against the trapezium. It is a fracture of the proximal end of the metacarpal of the thumb, oblique, and into the joint with the trapezium. The metacarpal bone is displaced backward. There is great

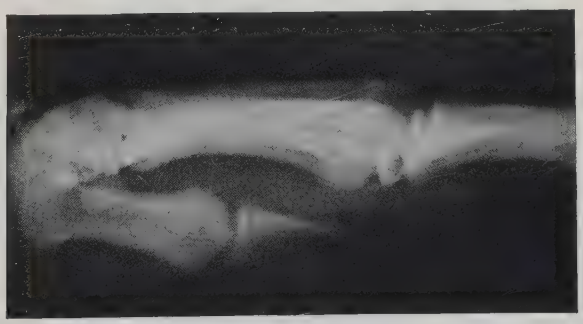

Fig. 772.—Roentgenogram of a complete lateral view of the metacarpal bones. In this view important displacements can be detected (George-Leonard).

disability in opposing the thumb and index-finger. Grasping small objects is impossible. Pressure upon the ball of the thumb is painful.

The injuries likely to be mistaken for this fracture are subluxation of this same joint, a sprain of this joint, and a contusion of this part. For treatment of Bennett's fracture see p. 458.

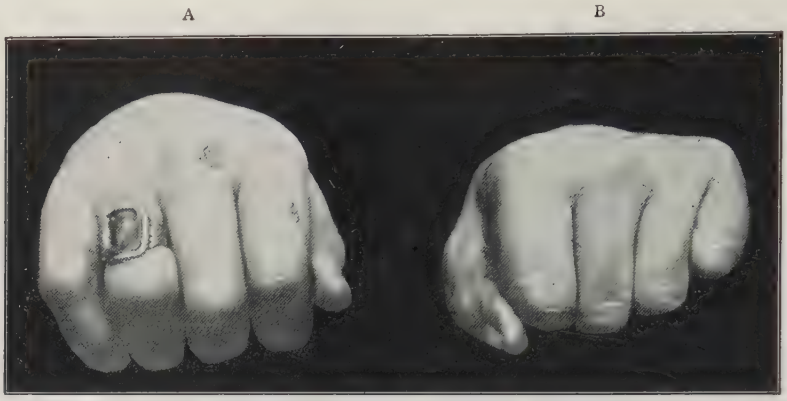

Fig. 773.—A, Fracture of neck of fourth metacarpal bone. Swelling of finger and knuckle. Knuckle has dropped downward toward the palm. B, Normal hand. Line of knuckles shown. Contrast with A.

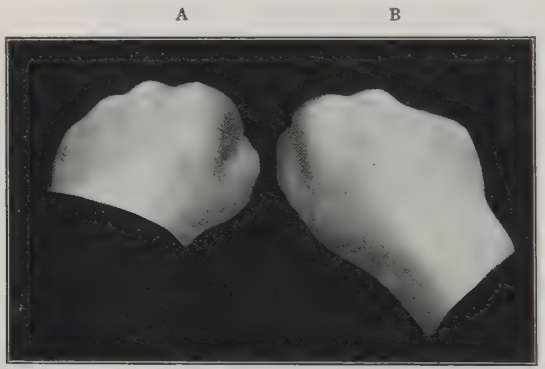

Fig. 774.—Fracture of the fourth metacarpal bone. View of two hands from behind: A Normal line of knuckles. B, Knuckle of the ring-finger has dropped downward. Deformity well shown.

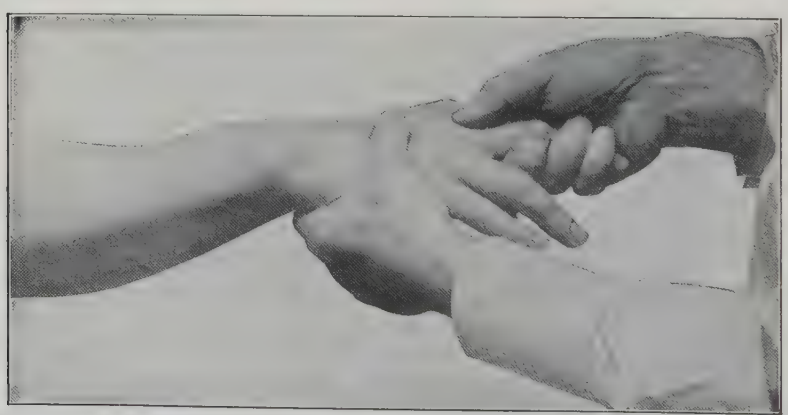

Fig. 775.—Method of grasping hand and finger in examining for fracture of metacarpal bone, and in reducing such a fracture.

Treatment.—After reducing the fracture of the metacarpal bone by traction and pressure, as suggested, it must be held in place by special pad-

ding, for the deformity tends to recur. The hand and forearm are supported upon a properly padded palmar splint. A pad is placed in the palm over the prominent lower end of the metacarpal. Another pad is placed upon the dorsum of the hand over the upper fragment. These pads are secured by narrow strips of adhesive plaster. The whole is then bandaged. If after carefully padding the two fragments and immobilizing them the

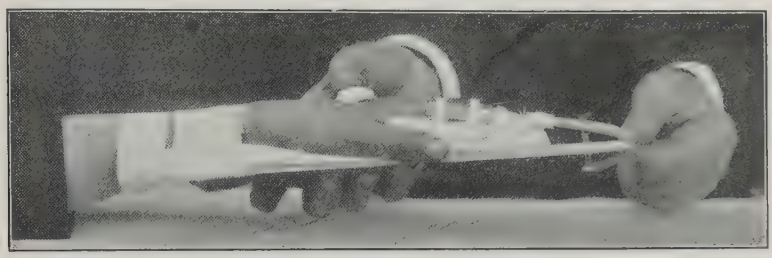

Fig. 776.—Fracture of the neck of the second metacarpal. Method of securing extension. Note adhesive plaster, rubber tubing, peg, padding to finger, pad over proximal fragment. Counterextension by adhesive plaster about wrist. Ready for the application of a bandage.

deformity is reproduced, the fragments slipping by each other, it may be necessary to make permanent traction upon the finger (Fig. 776). This is best done by applying narrow adhesive-plaster straps to the sides of the finger held in place by circular and oblique straps. The hand rests upon the palmar splint. An adhesive-plaster circular band passed about the

Fig. 777.—Fracture of the metacarpal of the index-finger. Use of roller bandage. Position of roller bandage. Method of traction and countertraction.

wrist and splint offers continuous countertraction. If the band is carried between the thumb and forefinger, greater security is obtained, and there is much less likelihood of slipping of the plaster. The extension upon the finger is obtained by fastening the extension strips to small pieces of rubber tubing, and carrying the tubing around a wooden peg or screw passed through a hole in the splint.

If it is not possible to hold certain fractures of the metacarpal bones accurately adjusted by ordinary non-operative means, operation and direct treatment is indicated.

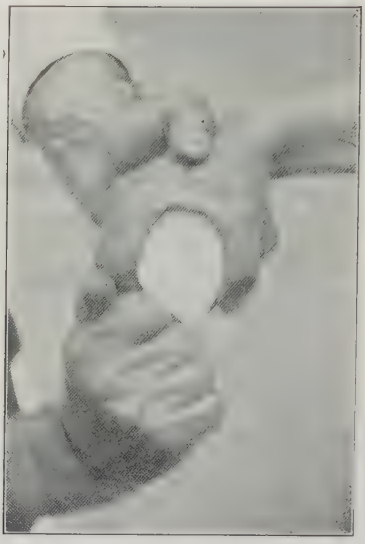

Fig. 778.—Fracture of the metacarpal of the index-finger. Completion of traction. Pressure and counter-pressure by thumb on the dorsum and on bandage in the palm of the hand.

A brad, nail, or screw carefully placed will often afford a perfect recovery of form and function.

A simple contrivance for certain fractures with little displacement is the use of a roller bandage (Figs. 776–779, inclusive). A roller bandage of cotton

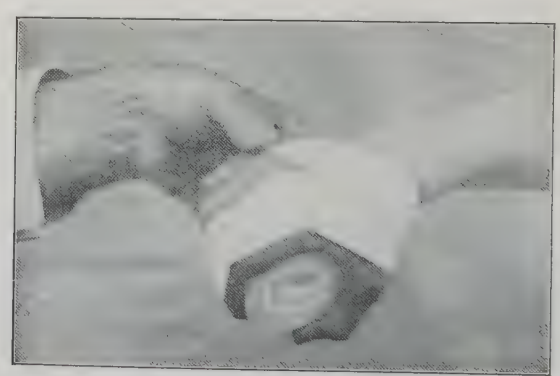

Fig. 779.—Fracture of the metacarpal of the index-finger. Completion of the application of the dressing. Adhesive-plaster straps holding hand and roller bandage in position.

cloth that is firmly and not easily compressed and of a size comfortable for the hand to grasp is selected. This is placed in the palm of the extended hand; the fingers and metacarpal heads are drawn down firmly over it. This position is maintained by a broad strip of adhesive plaster around the

Fig. 780.—Common fracture of the neck of the fourth metacarpal bone with some impaction.

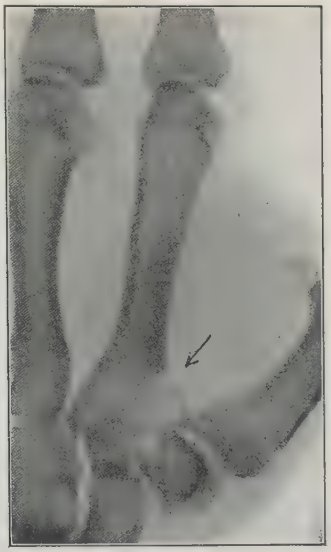

Fig. 781.—Oblique fracture, "stave" of the base of the second metacarpal bone. Joint opened.

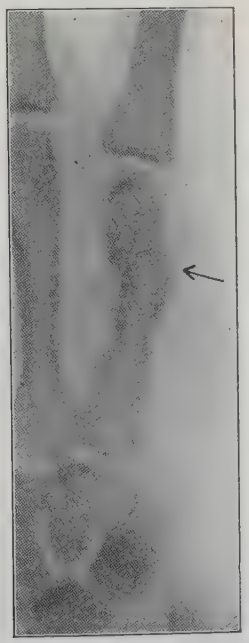

Fig. 782.—Fracture of the shaft of the fifth metacarpal bone.

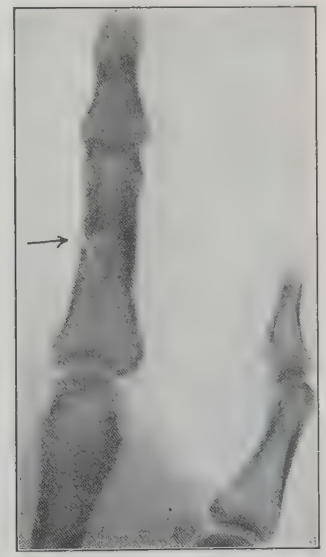

Fig. 783.—Comminuted fracture of the first phalanx of the index-finger without serious displacement.

whole hand. Pads, as with the palmar splint, may be used to reinforce the roller bandage. Unless great care is exercised this method will result in posterior bowing of the metacarpal bone. If there is an anterior displace-

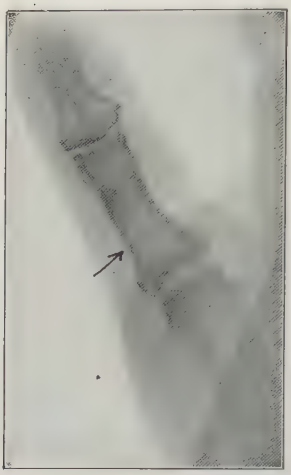

Fig. 784.—Transverse fracture of the first phalanx of the thumb, with some displacement and sliding by of distal fragment.

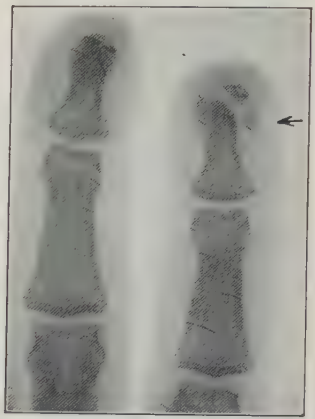

Fig. 785.—Fracture of the terminal phalanx of the index-finger.

Fig. 786.—Unusual fracture of the base of the terminal phalanx of the thumb.

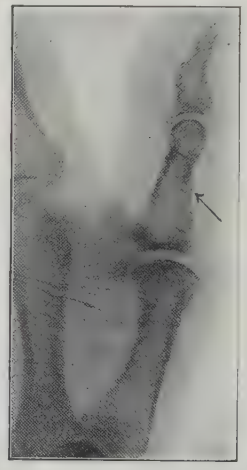

Fig. 787.—Oblique fracture (lateral view) of the shaft of the first phalanx of the thumb, some shortening.

Fig. 788.—Oblique fracture of the first phalanx of the thumb without much displacement.

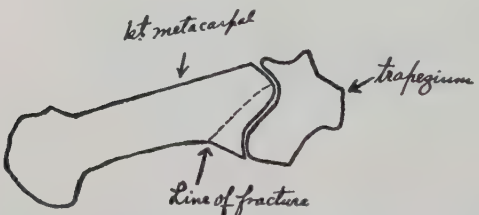

Fig. 789.—Showing diagrammatically the line of fracture at the base of the first metacarpal bone. Bennett fracture. Note that the joint is involved.

Fig. 790.—Oblique fracture of the fifth metacarpal bone near its base.

Fig. 791.—Fracture of the finger. Wooden splint applied to the palmar surface. Note straps and length of splint.

Fig. 792.—Finger splint of copper wire applied.

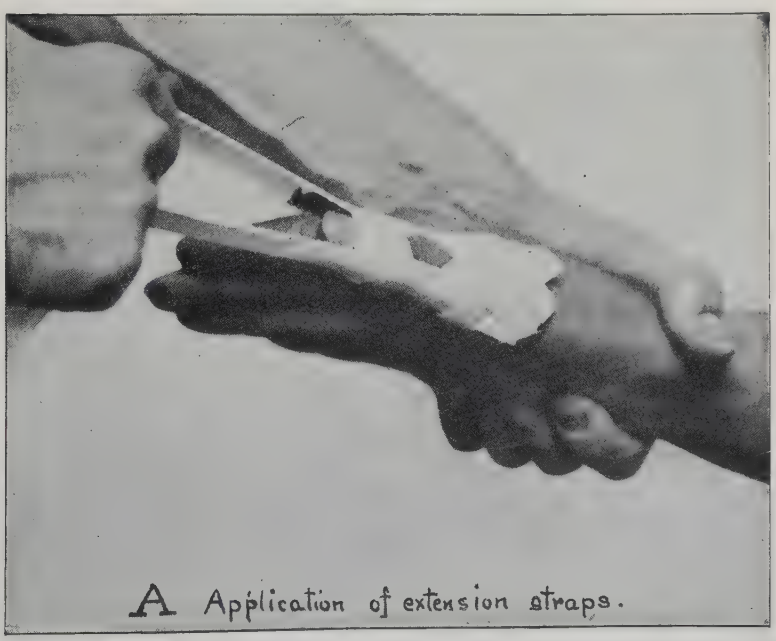

Fig. 793.—Fracture of the first metacarpal bone (Robinson).

Fig. 794.—Application of splint wood strips to lengthen extension trough in plaster spica to beyond the up of the thumb (Robinson).

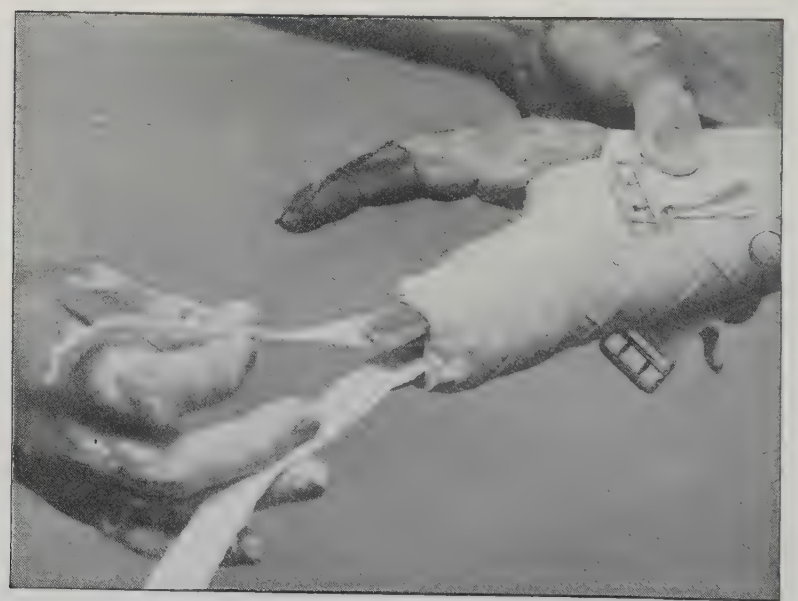

Fig. 795.—First plaster-of-Paris spica applied. Operator's left thumb should rest at O to depress plaster at the seat of fracture (Robinson).

ment of either or both fragments easily reduced and easily held, this roller-bandage apparatus is very efficient in maintaining reduction of the deformity.

This apparatus should be carefully inspected each day during the first week, to be sure that the position obtained is held firmly. After three weeks the splint may be omitted. Massage during the third week will be of bene-

Fig. 796.—Dressing completed. Splint wood withdrawn. Extension strips drawn tight over end of plaster trough and buckled (Robinson).

fit. Great care must be exercised in the use of the hand following the removal of the splint until the fourth week is passed, for deformity may result.

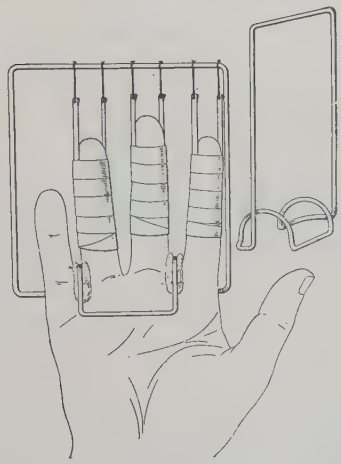

Fig. 797.

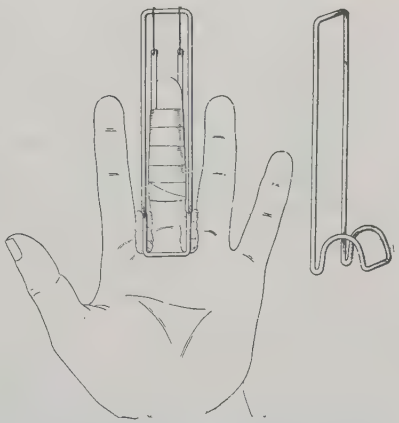

Fig. 798.

Figs. 797, 798.—Traction finger splint for single finger and for more than one finger (Hawley).

For the treatment of a Bennett fracture of the thumb a small palmar splint with traction upon the thumb and local pressure over the backwardly

dislocated fragment is good treatment. Robinson's device for accomplishing traction and local pressure are shown. In cases difficult to hold, this

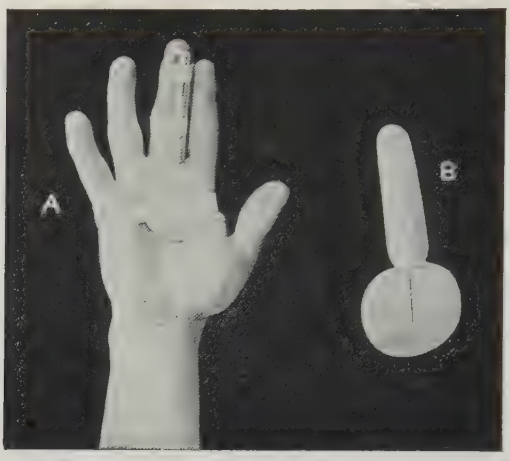

Fig. 799. Fig. 800.

Figs. 799, 800.—A, Finger splint applied to middle finger, three straps. Note position of splint in palm of hand. B, Finger splint of aluminum or tin, anterior surface.

method will be found efficient. After about two weeks gentle active motion is allowed. Massage should be begun the day following the injury.

FRACTURE OF THE PHALANGES

The bones lie subcutaneously; fractures of the phalanges are, accordingly, comparatively easy to detect. Fractures near the articular surfaces are hard to detect because joint crepitus is deceptive. The so-called base-ball finger may, in many instances, be associated with a fracture of the head of the metacarpal bone, and, involving the joint, occasion a slow convalescence.

Symptoms.—Crepitus, pain, and abnormal mobility are present, and occasionally deformity is seen.

Treatment.—It is important that the alignment of the phalanx be maintained. Rotation of the lower fragment upon its long axis is especially to be guarded against. Temporarily, if there is much swelling, the broken finger may rest upon a palmar splint, the two adjoining fingers serving as lateral splints to steady it. The contiguous skin surfaces must be protected by strips of cotton cloth and a drying powder. Traction, manipulation, and leverage are effective.

A single splint of thin wood, extending from the middle of the palm of the hand to the finger-tip, and held in position by adhesive-plaster straps, is most useful (see Fig. 791). The splint-wood used should be cut thin and not left thick and bungling—half the thickness of the wood of an ordinary cigar box is about right. The splint should be a little narrower than the finger itself. A narrow cotton bandage applied over the finger or a simple cot to cover the finger will be comfortable and will assist in immobilization.

Fig. 801.—Palmar wooden thumb splint. Note shape, pads, straps, position.

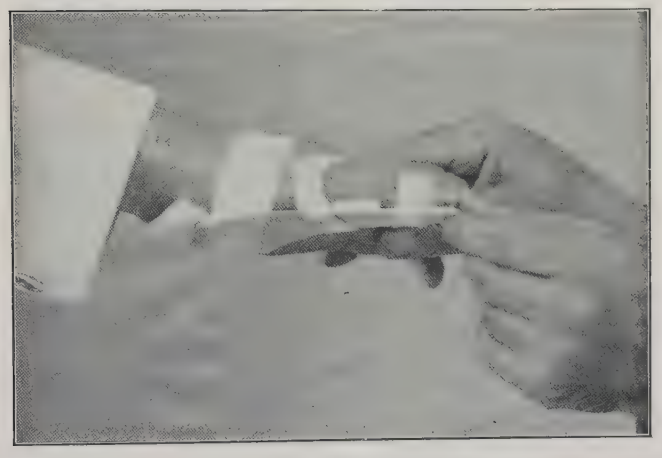

Fig. 802.—Lateral splint of wood for fracture of the thumb. Note pad at the side of first phalanx, to correct lateral deformity.

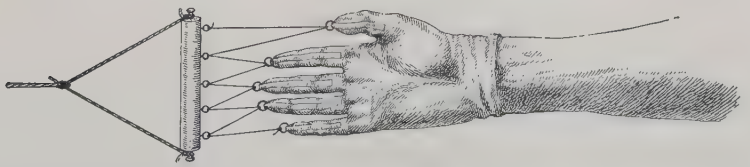

Fig. 803.—Methods of attaching traction to the hands and fingers. Cotton glove glued to hand. Curtain rings sewed to fingers of glove by means of tape. Traction made by laced cord, thus equalizing traction on the digits (Blake).

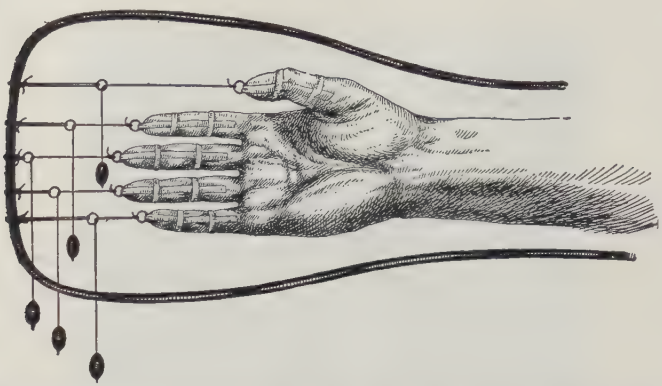

Fig. 804.—Methods of attaching traction to the hands and fingers. Curtain rings attached to digits by strips of adhesive, traction by individual weights, thus permitting greater latitude of movements of individual digits and exact determination of the amount of traction (Blake).

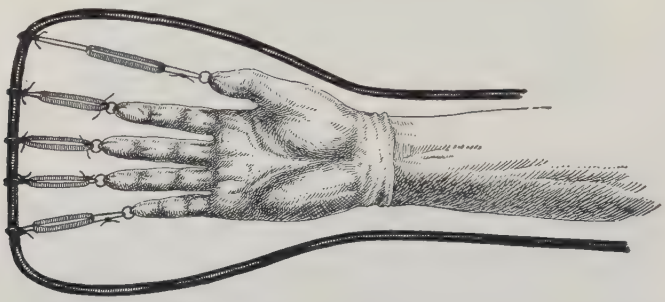

Fig. 805.—Methods of attaching traction to the hands and fingers. Cotton glove glued to hand. Curtain rings sewed to tips of fingers of glove. Traction by rubber elastics. This method is inferior to that shown in Fig. 803 as regards attachment of traction, and to that of Fig. 804 as regards application of traction (Blake).

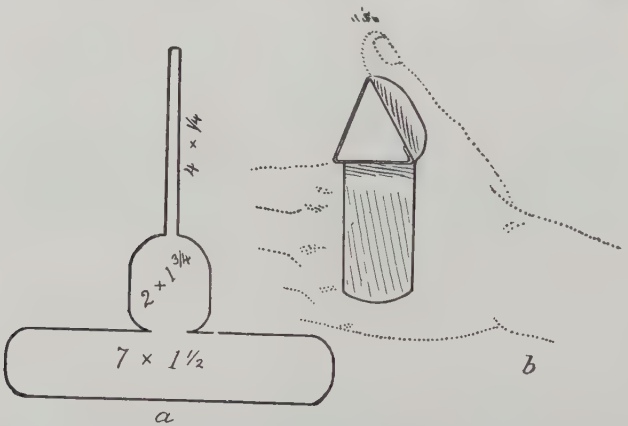

Fig. 806.—Thumb splint: *a*, Pattern—measurements are in inches; *b*, position of splint. Note extension of thumb (after Goldthwaite).

Ordinary letter-paper, by continued folding, may be made into a narrow and suitable splint. This is simple and efficient. It should be held in place by a bandage or, preferably, by a cot. Ordinary copper wire may be used,

as shown in the illustration, without any padding (see Fig. 792). This serves as a proper protection after the first week or two, and is not so clumsy as other splints. The aluminum or tin finger splint is easily made and satisfactory (see Figs. 799, 800). Any displacement in this fracture may be easily adjusted by narrow adhesive straps and small pads.

Fractures of the first and second phalanges of the thumb may be satisfactorily treated after reduction upon a dorsal or lateral splint of wood, if proper padding is employed (see Figs. 801, 802). Frequently, however, the tin splint fitted to the cleft between the thumb and forefinger, as shown in the illustration (see Fig. 806), will immobilize these fractures more securely and comfortably.

Open Fractures of the Phalanges.—These may be followed by profuse suppuration from necrosis of the fractured bones. This fracture is to be treated with extreme care, especially as regards antisepsis. Immobilization should continue at least four weeks. If at the end of this time union has not occurred, the patient may be given the option of continuing the treatment or of having the finger amputated. If union does not occur after four weeks of careful treatment, it is highly improbable that it will ever occur. Resection of the bones may be attempted before amputation.

CHAPTER XVI

FRACTURES OF THE FEMUR

Anatomy—Fracture of neck of femur in adults—Prognosis and results—Disability after fracture of the neck of the femur—Clinical types of—Physiological treatment (abduction)—Principles underlying—Impaction in hip fractures—Steps in applying the abduction treatment—Frog plaster—Light traction—Results of the old-fashioned "let-alone" treatment—The Bradford splint—Measurements for—Artificial impaction—Fracture of hip in childhood—Operative treatment—Separation of epiphysis of the great trochanter.

FRACTURE OF THE HIP OR NECK OF THE FEMUR

Anatomy.—The crest of the ilium can be felt throughout its entire extent from the anterior superior spine to the posterior superior spine. The pos-

Fig. 807.—Nélaton's line; passes from anterior superior spine of ilium to tuber ischii and crosses tip of great trochanter of femur, when thigh is partly flexed (Ashhurst).

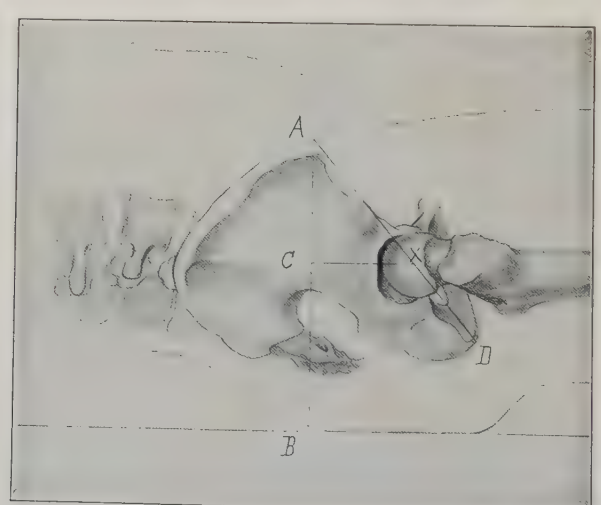

Fig. 808.—Nélaton's line (*A–D*) from anterior superior spine of the ilium to the tuberosity of the ischium. *A–C–X*, Bryant's triangle. Distance (*X–C*) from top of trochanter to perpendicular (*A–B*) dropped from anterior spine to horizontal table top is Bryant's measurement. After fracture this measurement may be less than normal.

terior superior spine corresponds to the level of the center of the sacro-iliac synchondrosis. The great trochanter of the femur is easily distinguished even in fat individuals. Nélaton's line (see Figs. 807, 808) is determined by stretching a tape from the anterior superior spine of the ilium to the tuberosity of the ischium. The top of the great trochanter lies at or a little below Nélaton's line, and about opposite to the symphysis pubis. The internal condyle of the femur looks in the same general direction as the head and neck of the femur (see Figs. 809, 810). The anterior superior spine of the ilium is of

Fig. 809.—Femur, from front. Note normal relation of direction of head and neck to that of internal condyle.

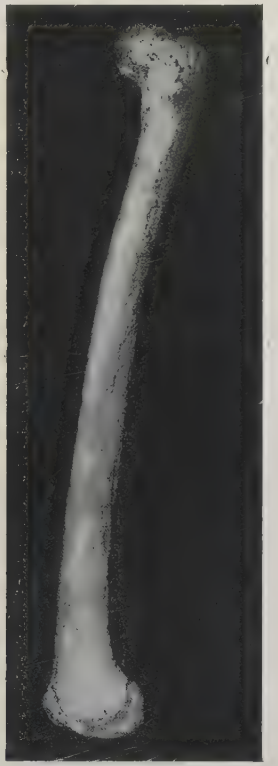

Fig. 810.—Femur, from outer side. Note normal anterior bowing and relation of direction of head and neck to that of internal condyle (see Fig. 820).

importance because from it measurement is made in taking the length of the legs after fracture of the femur. Normally, the fingers can be hooked behind the great trochanter toward the posterior surface of the neck of the bone. By this manipulation the posterior portion of the capsule of the joint can be felt.

Fracture of the Neck of the Femur in Adults.—This accident occurs most frequently in elderly people. It ordinarily is associated with a very slight injury, such as a trip and fall upon the floor from the standing position. Undoubtedly, in many instances the fracture precedes the fall. It

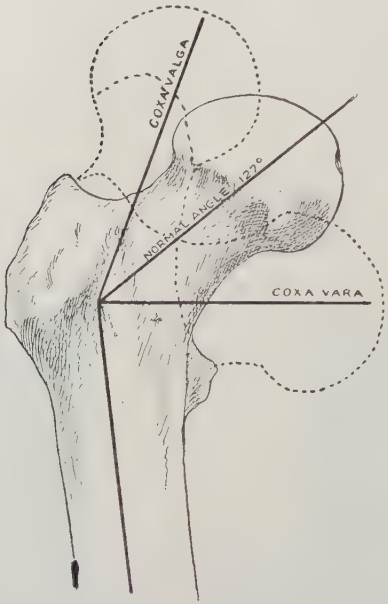

Fig. 811.—Normal angle of the neck to the shaft of the femur with the changes in position in coxa valga and coxa vara. (Davis, Applied Anatomy, after Nifong.)

Fig. 812.—Vertical section of hip-joint, seen from behind. The angle which the head under normal conditions forms with the shaft (127 degrees) is marked: *I*, Rim of acetabulum in vertical section; *C*, cavity of joint (exaggerated), showing the extent of the joint capsule; *L*, ligamentum teres (Eisendrath).

Fig. 813.—Adult femur. Upper portion of shaft and head and neck. The lines show the usual seats of fracture of the neck of the bone. Line 1 corresponds with Group 1; line 2 corresponds with Group 2; lines 2 and 3 correspond with Group 3.

Group 1. Fracture through the neck entirely within the capsule (see Fig. 834).

Group 2. Fracture through the neck at its junction with the trochanter major (see Fig. 835).

Group 3. Fracture through the trochanters often comminuted and combined with fracture of the neck at the base (see Figs. 832, 849).

is often difficult to determine the exact seat of the lesion. It is unnecessary to classify fractures of the neck of the femur according to whether they are within or without the capsule. Whether the fracture is within or without the capsule of the joint is of comparatively little moment excepting for prognosis. Neither is it of very great importance. An impaction according to the *x*-ray is often mistaken for an overlapping of portions of the neck due to displacements of the two fragments: abduction and flexion of the short

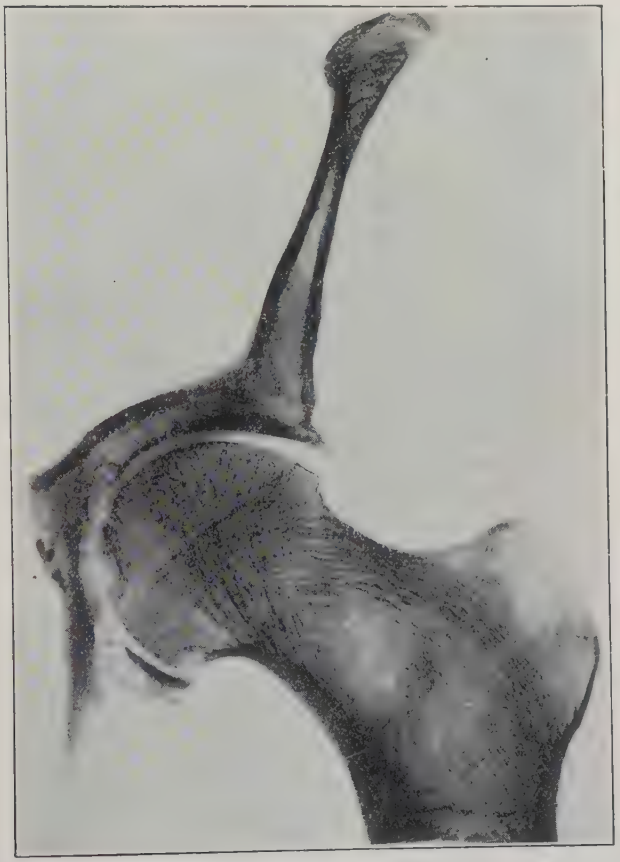

Fig. 814.—Roentgen ray of section through hip-joint. Note the trajectorium lines of resistance extending from femoral shaft upward, in erect position, through acetabulum. The approximate position of Ward's triangle is seen, the clear space in neck (Kolodny).

fragment and outward rotation of the long distal fragment. The really firm genuine impaction is a partial subcapital fracture in which the head is depressed somewhat backward as in the epiphyseal fracture of adolescence (Whitman). Certain of these cases will not need or demand reposition for eversion, external rotation will be essentially absent whether the fracture is impacted or unimpacted (see Figs. 852, 853). Fractures of the base of the neck of the bone—that is, fractures near the trochanter—are usually impacted. Fractures of the neck toward the head of the bone are usually unimpacted

Fig. 815.—A scheme of the mechanics of the neck of the femur. The drawing represents a central frontal section of the femur. Line *Gr–Gr* is the line of the axial pressure of the body weight, transmitted upon the tibia in the point *Gr*. Line *F–Gr* is the "neutral line," where neither pressure nor tension forces are transmitted. *W* is that portion of the body weight which is carried by the femoral neck. Line *A–B* is the line through which fractures of the femur would pass if the neck were a curved lever of a homogeneous structure. This line has been determined mathematically. Line *C–D* is the actual line through which fractures of the neck from vertical compression pass in elderly individuals. (Kolodny.)

(see Fig. 813). Impacted fractures unite readily, but occasionally may require breaking up or gentle replacement or replacement with artificial impaction, if they are impacted with very marked deformity so that the

Fig. 816.—1, Roentgenogram showing the experimental fracture of the neck of the femur of an elderly woman, in a testing machine. The line of fracture begins above at the outer edge of the eminentia of the neck. 2, Roentgenogram showing an experimental fracture of the neck of the femur of a man, in a testing machine. (Kolodny.)

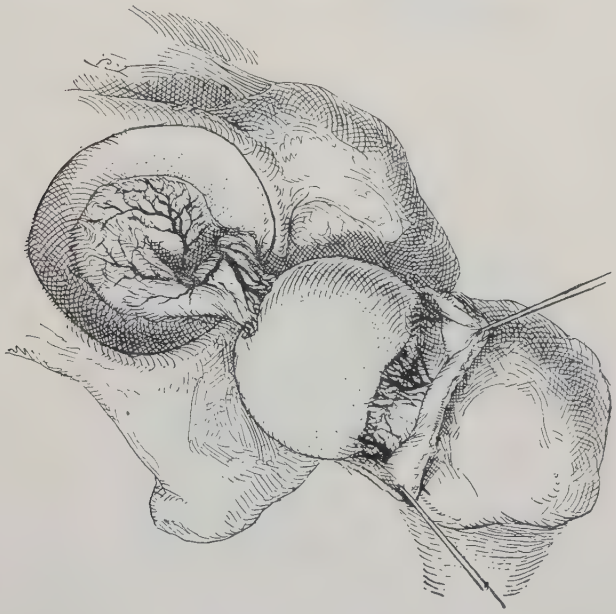

Fig. 817.—Drawing from an injected specimen of a newborn showing the blood-vessels running along the superior aspect of the neck toward the femoral head. Note the blood-vessels of the round ligament coming from the arteria acetabuli of the ramus posterior arteriæ obturatoriæ (Kolodny)

individual will be eventually distinctly handicapped in the use of the limb. Unimpacted fractures often remain ununited.

Fig. 818.—Roentgenogram of the upper end of the femur of a newborn injected with red lead, showing two main arteries of the round ligament coming from the common trunk with the blood-vessels of the pulvinar acetabuli (Kolodny).

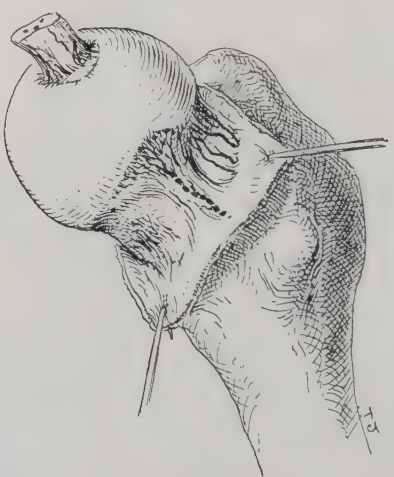

Fig. 819.—Drawing from an injected specimen of a newborn showing the blood-vessels running along the anterior and inferior aspect of the neck and entering the head mainly at the "Schenkelhalsspitze." The dotted line represents a blood-vessel embedded relatively deep in the periosteum of the neck (Kolodny).

Symptoms.—The patient ordinarily is unable to rise from the ground. A contusion may be seen over the hip as a result of the fall. There is pain

in the hip while the patient is lying still. This pain is increased upon motion at the hip. There is inability to move the injured leg easily and painlessly. There is limitation of motion of the injured leg. While lying upon the back

Fig. 820.—Note the forward arch of the shaft of the femur. This arching forward should be taken into account in the padding of splints in the case of femoral shaft fractures and in the final adjustment of supporting slings. This arch must be maintained.

it is impossible for the patient to raise the heel from the bed. The foot is everted, the leg having rolled outward. The whole extremity lies helpless

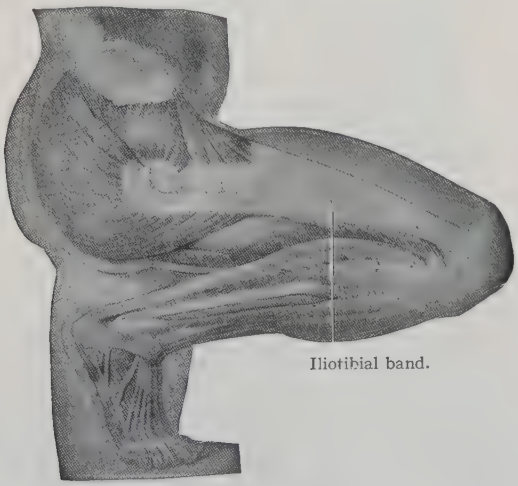

Fig. 821.—Note strong iliotibial thigh fascia with heavy muscular insertions at the upper part. It is the retraction of this extensive and strong fascia which often assists to make difficult reduction of femoral shaft fractures.

(Fig. 827). There is a slight appreciable fulness below the fold of the groin. This fulness in the outer upper part of Scarpa's triangle corresponds to a non-depressible area associated with fracture of the neck of the femur. Slight

shortening of the leg exists. After three or four days this shortening may increase to 2 inches. The trochanter is above Nélaton's line. The fascia above the trochanter is relaxed. This is especially noted in the standing

Fig. 822.—Drawing to show the anterior strong ligaments of the hip from pelvis to femur (anterior intertrochanteric line).

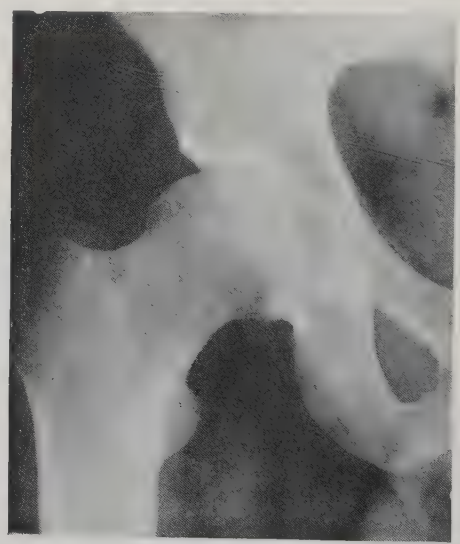

Fig. 823.—Roentgenogram of hip-joint with toes pointing directly upward; a perfect anteroposterior view. Note the lesser trochanter. Compare with Figs. 824, 825 (Arial George).

position, with the patient resting the weight upon the well leg (see Fig. 830). If the fracture is an impacted one, crepitus will be absent upon gentle manipulation unless the impaction has been broken up by some unwise means. If

Fig. 824.—Roentgenogram of hip-joint with the toes strongly inverted. Note absence of the full view of the lesser trochanter (Arial George).

Fig. 825.—Roentgenogram of the hip-joint with the toes turned in eversion as far as possible. Note appearance of head, great trochanter, and marked prominence of the lesser trochanter. Compare with Figs. 823, 824 (Arial George).

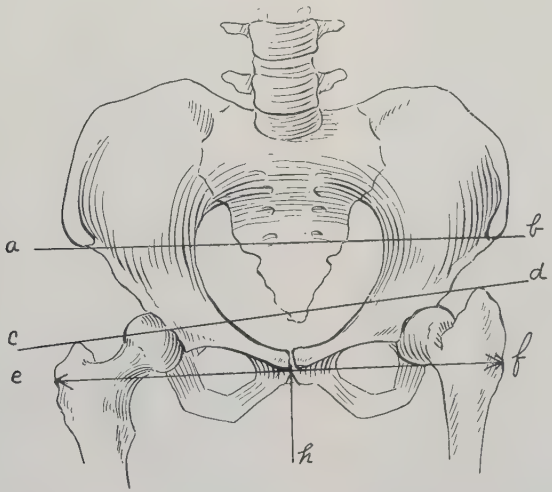

Fig. 826.—Drawing of the pelvis and hip-joints and femoral shafts. Note in fracture of the neck of the left femur elevation of the great trochanter obliquity of *c–d* as compared with *a–b*. Note that trochanter lies closer to the pelvis on the left or injured side, compare *e–h* and *f–h*.

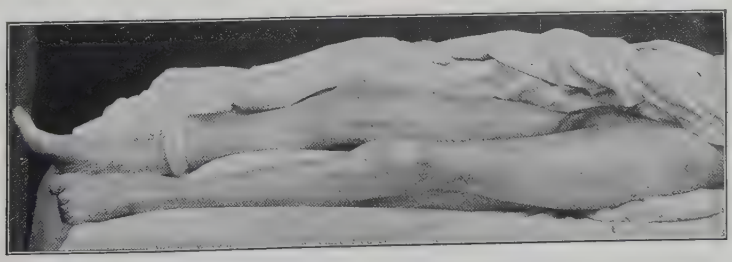

Fig. 827.—Impacted fracture of the left hip. Note helpless attitude of limb; foot everted.

the fracture is unimpacted, crepitus can be detected by the hand while traction or gentle rotation of the leg is made. The foot is everted whether impaction is present or not. If the impaction is of the anterior portion of the neck, inversion will be present; if the impaction is of the posterior portion of the neck, eversion will be present (see Figs. 828, 829). Impacted eversion cannot be inverted, nor can impacted inversion be everted without breaking up the impaction. In these cases of marked eversion and inversion a dislocation of the hip must be excluded if possible.

Examination.—A prolonged search for crepitus and abnormal mobility must never be attempted. A Roentgen ray, stereoscopic if possible, should be

Fig. 828.—Fracture of the hip. Inward rotation of the leg because of impaction of the anterior portion of the neck of the bone.

Fig. 829.—Fracture of the hip. Outward rotation of the leg because of impaction of the posterior portion of the neck of the bone. Compare with Fig. 827.

secured at as early a date as is practicable. In order to avoid unnecessary movement of the hip and because inspection and gentle palpation alone will so often decide the diagnosis, it is wise to follow a routine examination.

The history of the accident should be obtained. The presence and location of pain are determined. How much is the functional usefulness of the leg involved? What does inspection reveal as to the local condition and the position of the limb? What does palpation reveal? How do the measurements of the leg and the trochanter compare with similar measurements of the uninjured leg? Last—and to be avoided if a diagnosis has been reached—what does gentle manipulation show as to the presence of crepitus in the hip?

In order to make a systematic examination all clothing, of course, should be removed from the patient. He then should be placed upon a firm and

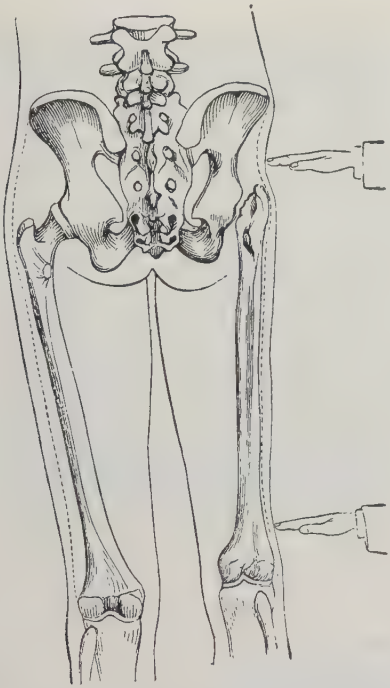

Fig. 830.—Note the method of recognizing the relaxation of the fascia lata following fracture of the neck of the femur. (Hamilton, Fractures and Dislocations, after Allis and Nifong.)

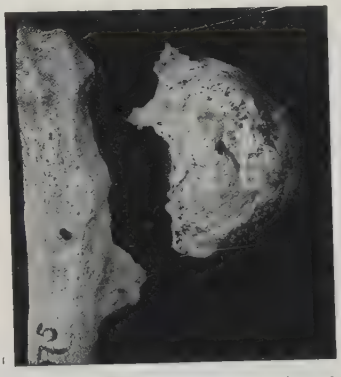

Fig. 831.—Old fracture of femoral neck; no union. Absorption of whole neck of bone. There is some atrophy of the whole shaft of the femur (Warren Museum, Specimen 8075).

Fig. 832.—Fracture of femoral neck. Impaction of base into the shaft (Warren Museum, Specimen 6303).

Fig. 833.—Bryant's line, a plumb line from anterior superior spine of ilium, patient supine (Ashhurst).

even surface. A hard mattress, a table, or a comforter spread upon the floor will provide the necessary conditions. An anesthetic is hardly ever necessary for diagnostic purposes. If an anesthetic is employed, the hip

should be handled in the gentlest manner possible. With an anesthetic all muscular spasm is abolished; therefore, movements of the hip are made

Fig. 834.—Fracture of the neck of the femur close to the head at outer part of the neck (Warren Museum specimen).

Fig. 835.—Fracture of the neck of the femur at base (Warren Museum specimen).

Fig. 836.—The type of fracture to which a Whitman or Brackett operation might be appropriately used, if the disability were severe enough.

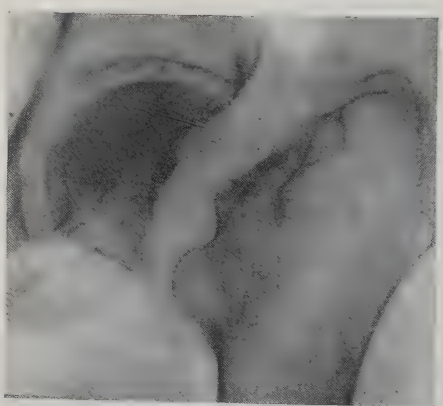

Fig. 837.—Fracture of the neck of the femur at the base of the neck or at the middle, with absorption of the intervening bone. The head remains intact. Note great shortening. Fibrous tissue union may give a useful though weak hip. Such a case may be helped by support to low spine, sacrum, and the hip. If greatly incapacitated, a Whitman or Brackett operation might be indicated (Healy).

without the protection of voluntary muscular spasm. All sudden quick movements should be avoided. There is great danger that an impacted fracture of the hip may be changed by rough handling, especially in the

movement of rotation, to an unimpacted fracture. Palpation of the neck of the femur with the thumb in front of, and the fingers behind, the great

Fig. 838.—Fracture of the neck of the femur. Bony union treated by the Whitman method. Compare with other hip in Fig. 839 (Healy).

trochanter will detect any irregularity or thickening and tenderness about the neck of the bone (see Fig. 857). By palpation of the great trochanter

Fig. 839.—Compare this normal hip with result of fracture. Same patient as Fig. 838 (Healy).

one may discover there the seat of fracture. Swelling, tenderness, and crepitus may be found. Only gentle strong traction in the line of the long axis of the thigh should be made to elicit crepitus and abnormal motion.

Measurement.—The absence of any pre-existing injury or disease of the hip under consideration is always to be carefully noted. Measurement should always be made with the patient lying on the back. The leg should be brought gently alongside of its fellow, and steadied by an assistant.

Fig. 840.—Fracture of the neck of the femur. Note the rotation of the head and union with the impacted neck. Compare with normal hip of same patient, Fig. 841 (Healy).

Measurement should be made from the anterior superior spine of the ilium to the internal malleolus upon each side (see Fig. 968). If there is shortening upon the injured side, a fracture with some displacement is likely to have occurred. A normal difference in the length of the lower limbs is,

Fig. 841.—Same patient as Fig. 840. Normal hip for comparison.

however, not unusual. It is, therefore, necessary to determine the presence of asymmetry if it exists, if any confidence is to be placed in the measurements of the legs. Measurements should, therefore, be made of the tibia upon the two sides, and these compared. If no asymmetry appears to be

present, any differences in measurement may be taken to be absolute. If it is impossible to bring the legs parallel, they must be placed in the same relative positions to the median line of the body.

Fig. 842.—Fracture of the neck of the femur fifty years previously. Note the result, not treated by abduction method, comparing it with the normal hip (Fig. 843) of this individual (Healy).

Bryant's method of measurement is simple and of service (Figs. 808, 833). The limbs are placed symmetrically. The top of the trochanter is marked

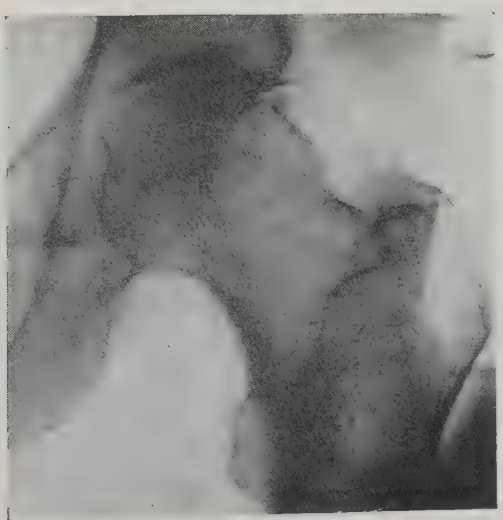

Fig. 843.—Normal hip of patient shown in Fig. 842. Compare this with hip fractured fifty years ago. Not treated by the Whitman method (Healy).

upon the skin. A perpendicular line is dropped from the anterior superior spine to the table upon which the patient lies. Measurement is made from

the top of the trochanter to this perpendicular line. If fracture of the neck of the femur has occurred, and there is displacement or shortening of the limb, the distance from the perpendicular to the top of the trochanter will

Fig. 844.—Fracture of the neck of the femur at the middle. Solid union after Whitman treatment (Healy)

be less than a like measurement on the uninjured side. The position of the top of the great trochanter is determined with reference to Nélaton's line. If the leg is rolled outward, dislocation of the hip forward would be

Fig. 845.—Fracture of the neck of the femur near the head. Compare anatomical result with normal hip, Fig. 846 (Healy).

Fig. 846.—Normal hip of case shown in Fig. 845.

suspected, but the absence of the head of the bone anteriorly and the absence of other positive signs should eliminate dislocation. If the leg is rolled inward, a dislocation of the hip upon the dorsum ilii would be considered. The absence of other positive signs of dislocation and the presence of the

head of the bone in the acetabulum should convince one of the non-existence of dislocation. In an elderly person who presents no well-marked sign of fracture, but who is unable to use the limb after ever so slight an injury,

Fig. 847.—Fracture of the neck of the femur about the middle. Note almost perfect anatomical result. Whitman method. (See Fig. 848.)

a fracture of the hip should be so strongly suspected that, until the Roentgen ray proves it absent, he should be treated as if a fracture were present.

A diagnosis of a simple contusion or sprain about the trochanter or the hip following a fall in an elderly person should not be made until careful

Fig. 848.—Normal hip of case in Fig. 847. Compare the two.

stereoscopic Roentgen rays have proved the absence of an impacted or fissured fracture.

An elderly person may fall, have little or no immediate pain in the hip, have no functional disability, *i. e.*, be able to make all the usual movements of the hip, have none of the classical signs of fracture, and yet have a frac-

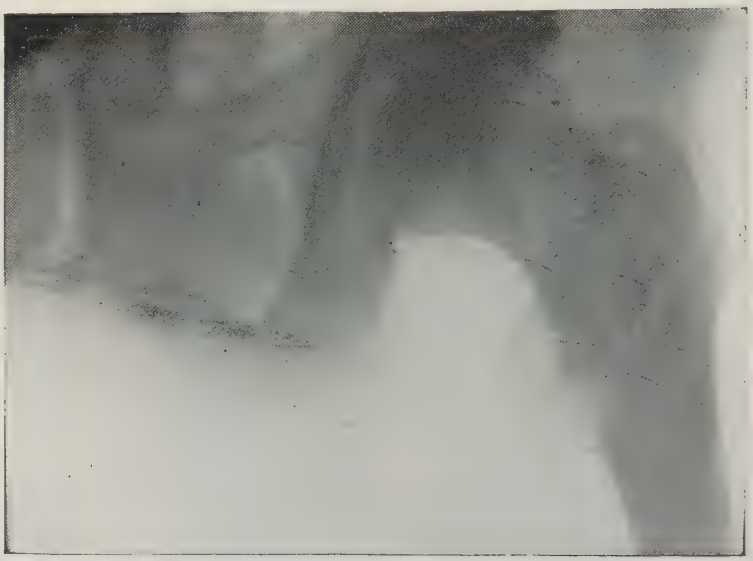

Fig. 849.—Fracture of the shaft through trochanters. Lesser trochanter above line of fracture. Solid union follows (Dodd).

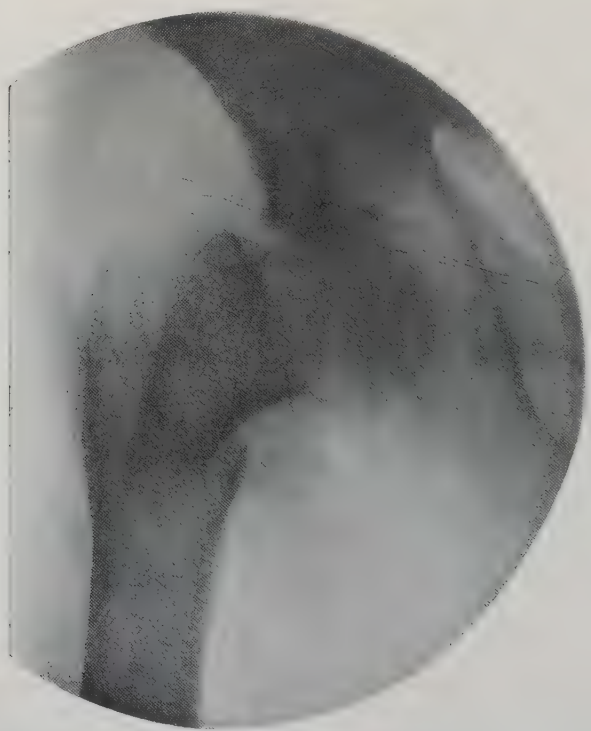

Fig. 850.—Fracture of femur through trochanters. Lesser trochanter below line of fracture. Usually solid union follows. Note line of fracture by following inner line of cortex. This position of fragments should be corrected by great abduction and slight traction. Such a fracture should not be allowed to heal in this position (Dodd).

ture of the neck of the femur. This fact should stimulate very careful x-ray examinations in injuries to the hip in elderly people.

Prognosis and Result.—In the very aged and feeble the shock of a fracture of the neck of the femur is severe. The danger to life in these cases is great. The fracture may be a terminal condition, the last straw in the balance. The frail, elderly woman with cardiovascular renal disease, who becomes, after the fracture injury, slightly mentally wandering and delirious may die after a week or ten days. In such cases the folly of attempting reduction is obvious. An elderly patient may die of shock within two or three

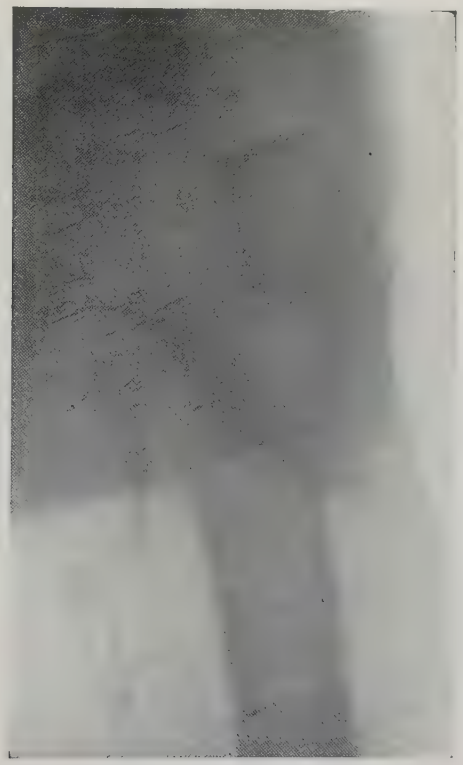

Fig. 851.—Fracture of the upper part of shaft of the femur below the trochanters (Dodd).

days, or within a week of hypostatic pneumonia, or may live several weeks and die of exhaustion because of pain and the enforced confinement.

If the fracture can be treated by proper reduction and immobilization, union will occur in most cases. The impacted cases and the unimpacted cases will usually unite if properly treated by artificial impaction (see p. 515). Chronic rheumatism may prevent a fractured hip from ever becoming useful.

If a fracture of the neck of the femur does not show union after eight weeks, non-union may be regarded as present. There is no such thing as delayed union following fracture of the neck of the femur.

Non-union of the hip fracture does not preclude a useful limb (see Fig. 858). Ununited fractures of the hip are greatly benefited by proper ambulatory apparatus. They may be made to unite by mechanical means even several weeks and months after the injury. A bone-graft, by means of a bone-peg which passes through the great trochanter and into the neck and head of the bone, will secure union of the fracture of the neck. This is particularly true of fractures occurring in young adults.

Disability After Fracture of Neck of Femur.—There are several possible disabilities following fracture of the neck of the femur: Shortening of the

Fig. 852.—The rotation of the head, with an increase of the angle of the femoral neck and the deep impaction of the neck into the trochanteric fragment are clearly seen. The angular deformity with overriding is shown in the inner side of the neck. Woman sixty-four years old. Walked alone, with very little pain, immediately after the accident. (Speed, Annals of Surgery, February, 1924.)

limb. Slight eversion of the foot. Some limitation in the extreme motion at the knee. Some limitation in certain hip movements in the extreme positions. A slight limp, a feeling of weakness and insecurity.

If the form of treatment chosen for a given case is appropriate and is carefully followed out, the result of fracture of the neck of the femur is a useful hip without marked disability and in many instances without any disability whatsoever.

If there occurs a linear fracture through the neck of the bone, it is usually obliquely linear, without displacement. This fracture does not require re-

position. Simple support and moderate immobilization for about four to eight weeks will be necessary. Active daily movement of the knee, ankle, and hip may be permitted while the patient lies in bed on the back. Such

Fig. 853.—The fracture extends high into the head of the bone. The head of the femur is rotated so that the neck angle is increased instead of diminished. The impaction is deep and in the outer aspect of the neck more than the inner, on account of the head rotation. The overriding is plainly seen again on the inner aspect of the neck. Walked upstairs immediately after the accident. (Speed, Annals of Surgery, February, 1924.)

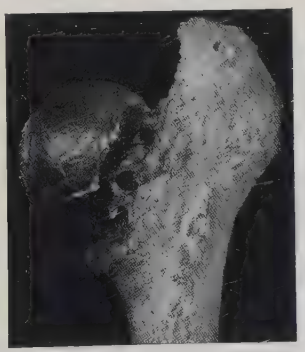

Fig. 854.—Fracture of femoral neck, unimpacted; fibrous union, with absorption of the neck (Warren Museum, Specimen 3651).

a fracture requires adequate protection from weight bearing for six months to a year. Thus will postfracture pain, disability, and coxa vara be avoided.

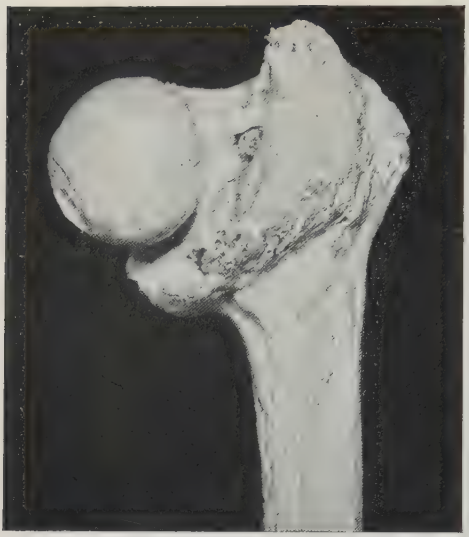

Fig. 855.—Fracture of the neck of the femur (Warren Museum specimen).

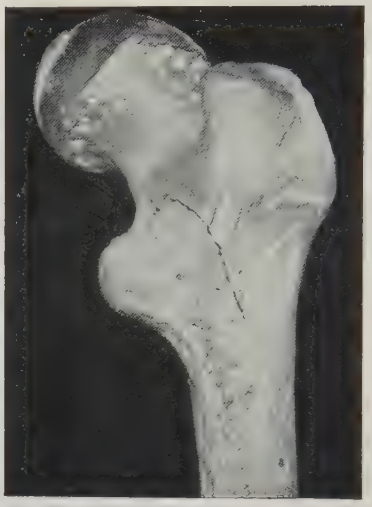

Fig. 856.—Note line of fracture extending into shaft.

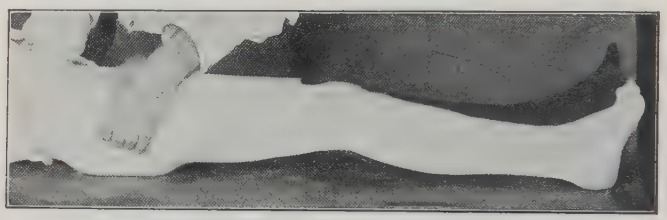

Fig. 857.—Method of palpating the trochanter of the right femur.

Fig. 858.—Man forty-five years old. Fracture of the neck of the femur. Union ligamentous, with displacement. A useful limb was secured (*x*-ray tracing).

Clinical Types of Fractures of the Neck of the Femur.—1. Central loose type of fracture, seen early. This is the common fracture, without impaction (Fig. 838).

2. Incomplete and impacted fracture: (*a*) This will include the linear type without displacement—the slightly impacted kind. (*b*) The neck is shortened, the angle of the neck is preserved—the much impacted variety, which is rather rare.

3. Very feeble persons with either the first or second type of fracture.

4. Central loose type of fracture seen after some time has elapsed.

5. Fracture of the neck of the femur in childhood (p. 517).

Treatment of Fracture of the Hip.—The surgically efficient treatment of the fracture of the neck of the femur will be the most conservative and satisfactory treatment for the patient.

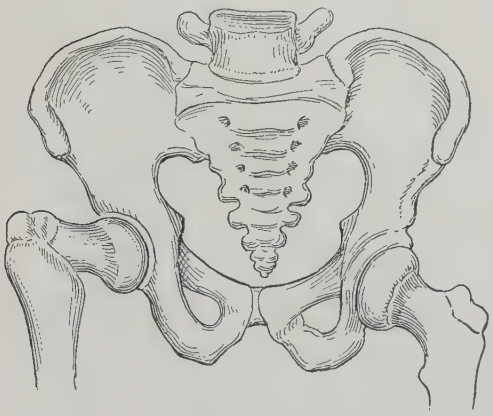

Fig. 859.

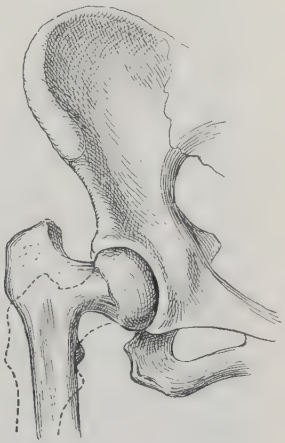

Fig. 860.

Figs. 859, 860.—Coxa vara following fractured neck of femur. (From Moorhead, Traumatic Surgery.)

Methods of Treatment.—(*a*) Abduction, etc., plaster-of-Paris splint (Whitman).

(*b*) Abduction, frog position, plaster-of-Paris splint (Moore-Straus).

(*c*) Extension (Buck).

(*d*) Abduction with traction splint (Bradford).

(*e*) Artificial impaction, plaster-of-Paris splint (Cotton).

(*f*) Operative treatment for non-union (p. 961):

Refreshing bony surfaces.
Removal of head of bone.
Bone peg.
Bracket operation.
Whitman operation.

General Considerations.—Fractures of the hip or of the neck of the femur demand the greatest tact in their management. The aged respond readily

to care. The patient should be made to feel as comfortable as possible while confined to his bed. Particular attention should be paid to diet and to all little comforts. The discomforts attendant upon immobilization are often great. Let the days spent in bed be made especially attractive. Be sure that agreeable friends visit the patient, seeing to it that they do not stay so long a time as to weary him. Let them interest him in the news of the day, so that he may feel that he is keeping up with events. Employ a skilled nurse to minister to his wants; a bright and cheerful woman nurse is ordinarily better than a man nurse. The pulse is to be carefully watched as well as the

Fig. 861.—Ununited fracture of the neck of the femur treated by bone transplantation. Bony union; no shortening; free motion. Note peg *in situ* (Ashhurst).

respiration. A moderate amount of alcohol once or twice a day with meals is to be used. The courage of the aged needs bracing. Bed-sores develop with surprising rapidity. Skilled watchfulness and immediate treatment will often check the progress of a red pressure spot. The part exposed to pressure should be kept very clean with soap and warm water; it should be bathed with alcohol, thoroughly dried, and well dusted with powder (starch and oxid of zinc, equal parts); and the pressure should be relieved by proper pads or cushions. If the heel is the part involved, a rubber cushion or a ring made of sheet wadding wound with a bandage may be used. A certain amount of moving about in bed should be granted to old people

Asthenic hypostatic pneumonia from long-continued resting in one position is not uncommon. Therefore, moving about a little in bed, to the extent of sitting upon a bed-rest at varying angles, is beneficial. Deep rhythmic breathing while lying flat on the back is a splendid stimulator of the circulation. In the case of a fracture of the neck of the thigh bone occurring in an elderly individual have great regard for the general condition of the patient and immobilize the fracture by that method which seems to best meet the anatomical conditions.

The old adage "Treat the patient and let the fracture go" no longer obtains. We can apply as efficient treatment to the fractured hip in the aged as in the young adult; and such rational treatment should be applied whenever possible, and it is almost always possible. The *general* care of an aged patient is none the less important because the treatment of the fracture is on a rational basis.

(*a*) **The Physiological Treatment.**—The abduction method has three great advantages over any other method—comprehensive mechanical effectiveness, single control, and general availability (Whitman). This method has proved to be a most satisfactory and effective treatment for fracture of the neck of the femur.

Principles Underlying the Abduction Treatment.—Recognition of the pathology of the fracture; recognition of the anatomy of the hip.

The proximal fragment is of small size. There is little or no callus seen outside the line of fracture. The process of repair requires the security of exact apposition of the fractured surfaces. Fragments must be in as exact contact as possible—as in a grafting operation—to meet the local needs for the immediate repair.

In fracture of the neck of the femur, the head being fixed in the acetabulum, the displacement is always of the outer, or limb fragment. This displacement of the distal fragment depends upon the force of the accident and the muscular action of the powerful group of muscles attached to and about the great trochanter, namely, the obturator internus and externus, the gluteus medius and maximus, the pyriformis, the quadriceps femoris and the iliopsoas. If the separation is complete the displacement is usually upward, backward, and outward, and to appose the fragments the limb must be lifted forward, rotated inward, and drawn downward to its normal length. But, since the neck of the femur projects from the shaft at an angle, the apposition is in a lateral relation and is unstable because there is no point of resistance. If now, the limb be abducted to the normal limit, the extremity of the neck is brought down to a horizontal plane. As the capsule surrounds each fragment its tension, consequent on abduction, aligns them, and since the head is fixed by the acetabulum, forces an end-to-end and resistant contact. Furthermore, at the limit of abduction the upper border of the shaft fragment and the trochanter are apposed to the rim of the acetabulum and the side of the pelvis. Thus, security is assured by the tense capsule, by direct and indirect bony contact, and by the muscular impotence incidental to the attitude of complete abduction (see Figs. 867–880).

Impaction in Hip Fractures.—The traditional impaction is a firm implantation of one fragment in another, or other resistant relation that assures contact and thus repair. This is, however, in connection with hip fractures, merely a clinical conception, suggested either because the deformity is slight or because some voluntary control of the limb is retained, which is rarely confirmed by *x*-ray examination, or by the test of reduction. Deformity to a degree to embarrass function should always be corrected even if resistant, because the manner by which this is accomplished has no analogy to the "breaking up of an impaction," and because the more accurate adjustment of the fractured surfaces assured by correction, far from endangering union, is in many instances the only means of assuring it.

Exact position of the limb to be sought in most fractures of the neck.

When this adjustment has been accomplished, a long plaster spica is applied, fixing the limb in full extension, full abduction, and slight inward rotation. Although the spica is a direct support, its chief function is to hold the limb in the selected attitude that makes the internal or anatomical splinting effective, as may be demonstrated by *x*-ray examination through the plaster at intervals of weeks or months.

The abduction method is adequate because it utilizes the construction of the joint and its mechanical environment to reduce deformity and to fix the fragments in apposition.

Steps in Applying the Abduction Treatment

1. Complete anesthesia.
2. Proper sacral support, or fracture table.
3. Two assistants. Reduction of shortening by manual traction.
4. Lifting upper thigh to level of sound side.
5. Rotation inward of injured thigh.
6. Abduction of the sound hip to the limit.
7. Abduction of injured side to limit set by sound side.
8. Fix limbs in complete abduction, full extension, slight inward rotation, knee slightly flexed.
9. Foot at right angle with leg and slightly adducted.

Application of Fixation Plaster-of-Paris Splint.—*The Long Plaster-of-Paris Spica.*—The patient clothed only in fitted shirting or a combination suit of underclothing, having been anesthetized, is lifted to a pelvic rest screwed to the end of the table (Hawley) and provided with a perineal bar for counter-pressure (see Fig. 885), the shoulders resting at an equal height. The limbs, extended and side by side, are each supported by an assistant. Direct manual traction on the limbs is then made by the assistants against the resistance of the perineal bar, while the surgeon, standing on the injured side, lifts the thigh upward, guiding the trochanter to its normal position.

When the shortening has been reduced as demonstrated by comparative measurements, the limb, which is usually rotated outward, is turned until the patella points slightly inward. The two assistants, still exerting equal traction on the limbs, then abduct them, that on the sound side slightly in advance, in order to demonstrate the normal range and to balance its fellow, so that the tension on the capsule as the fracture is adjusted may

not tilt the pelvis upward. A final inspection shows the extended limbs equally abducted on a level pelvis with all the landmarks corresponding. Attention is again called to the order of the manipulation, direct manual

Fig. 862.

Fig. 863.

Fig. 862.—Complete fracture of the neck near the base (Whitman).
Fig. 863.—After removal of the plaster spica showing the process of repair and the restoration of the normal angle of the neck assuring the range of abduction (Whitman).

reduction of the shortening, and inward rotation preceding the abduction (see Figs. 870, 873).

The so-called impactions are usually reduced as easily as those that are evidently complete, resistant cases being far more often encountered in

Fig. 864.

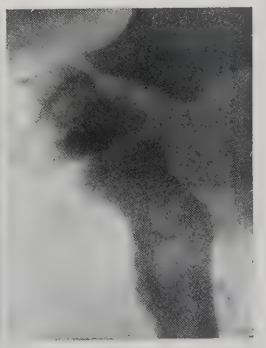

Fig. 865.

Fig. 864.—Typical incomplete fracture in childhood (Whitman).
Fig. 865.—After reduction by the abduction method (Whitman).

early life, when the fracture may be incomplete or of the epiphyseal type. The impacted fracture has lost its former significance, because the abduction method assures reduction without violence, supplemented by immediate and secure fixation.

Position of Lower Limbs After Reduction.—The typical attitude in which the limb is fixed after adjustment of the fracture is one of complete ab-

Fig. 866.—Showing the range of normal abduction and its limitation by bony contact on one side, and the depression of the neck and limitation of the abduction consequent upon uncorrected deformity on the other (Whitman).

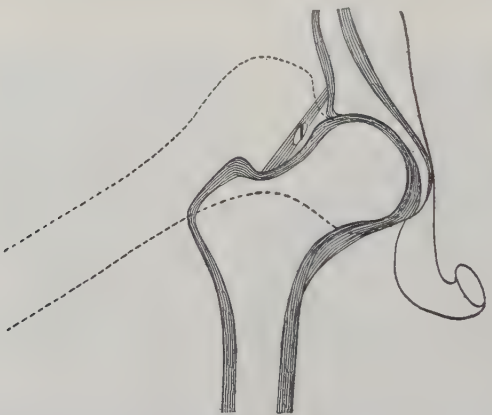

Fig. 867.—Section of a hip-joint. The dotted outline illustrates limitation of the range of normal abduction by contact of the outer border of the neck with the upper border of the acetabulum and of the trochanter with the tissues covering the side of the pelvis (Fick).

duction, complete extension, and slight inward rotation. The knee is slightly flexed and the foot slightly adducted and in a right angular relation to the leg.

The Abduction Plaster-of-Paris Spica.—In the application of the spica the body and limb are first carefully protected. A close fitting shirting or a "union suit" of underclothing is drawn on and covered by bandages of sheet wadding, and Canton flannel made especially thick about the upper

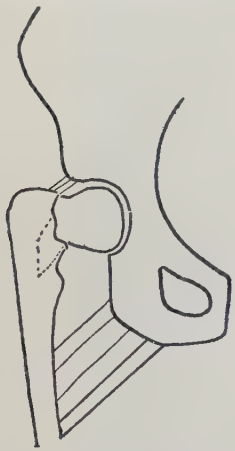

Fig. 868.—Impacted fracture of the neck of the femur, illustrating the limitation of abduction caused by the deformity (Whitman).

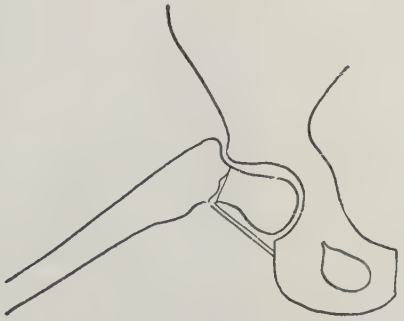

Fig. 869.—Illustrates the restoration of the normal angle by forcible abduction (Whitman).

part of the chest, the pelvis, and the sacrum may be used. The plaster support should extend from the nipples to the tips of the toes. It should

Fig. 870.—Fracture of the left hip. Note abduction. Rotation inward of left lower extremity; slight hyperextension of thigh. Plaster splint being applied. Traction on left leg. Right leg being steadied in complete abduction (Whitman).

be thick and unyielding about and below the joint, completely covering and enclosing the buttock. The spica is usually strengthened at the hip by the insertion of one or more thin steel bars.

Fig. 871.—The plaster spica properly applied in complete abduction, complete extension, and slight inward rotation. The elevation of the head of the bed is shown (Whitman).

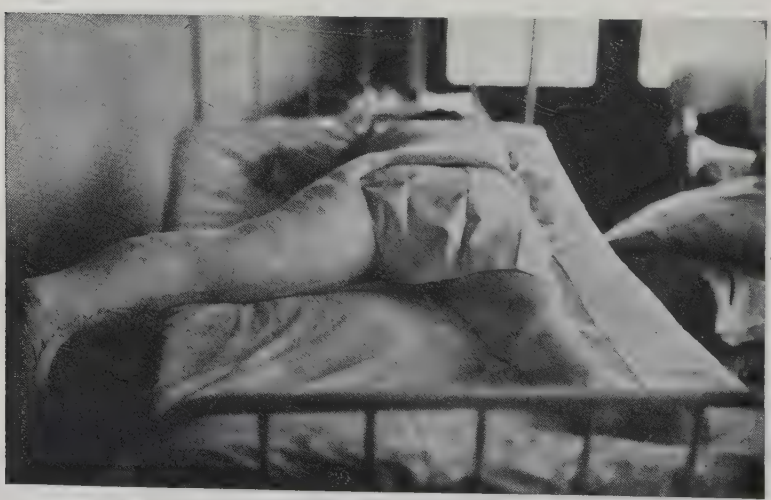

Fig. 872.—Fracture of the left hip. Same as Fig. 870 after application of plaster splint. Prone position. Note degree of abduction (Whitman).

The spica should be cut at the pelvis to permit the full flexion of the sound thigh. If the patient complains of constriction of the chest it may be split at the top, or an opening may be made over the abdomen. Another

covering of shirting may be drawn over the plaster and sewed to the first, thus binding the margins with thick soft material.

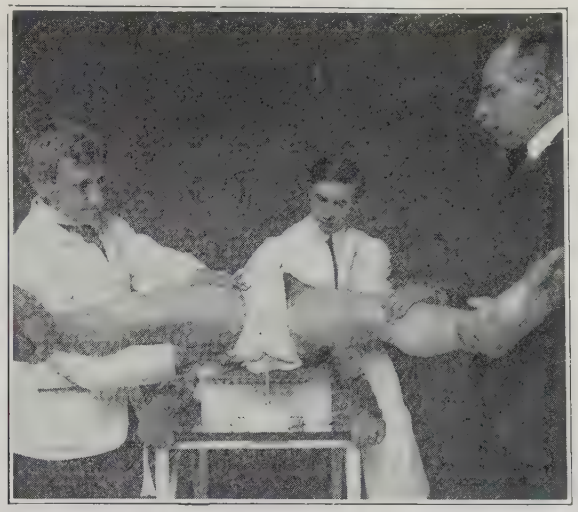

Fig. 873.—Impacted fracture of the neck of the right femur, illustrating the reduction of the deformity by direct traction and abduction. The operator supports the joint. The left limb is abducted to indicate the normal range, which varies in different subjects, and to prevent tilting of the pelvis. Patient placed on table (Whitman).

Fig. 874.—The long spica as applied for the treatment of fracture of the neck of the femur in the adult at an angle of abduction of 45 degrees (Whitman).

Explanation of Methods: Details.—As has been stated, the purpose of the support is to assure anatomic rather than direct splinting. The long spica is most effective because the leverage above and below the joint is fairly

equal. The limb is hyperextended in order that the strong anterior wall of the capsule may be made tense and because support in this position checks any tendency to backward displacement of the outer fragment to which the force of gravity predisposes. Slight flexion at the knee reduces the strain on the joint, and the inward rotation follows the principle of overcorrection of the pre-existing deformity. When the plaster is firm the patient is placed in bed, the head of which has been raised a foot or more by blocks. This inclination compensates for the pillow and, in contrast with the elevation

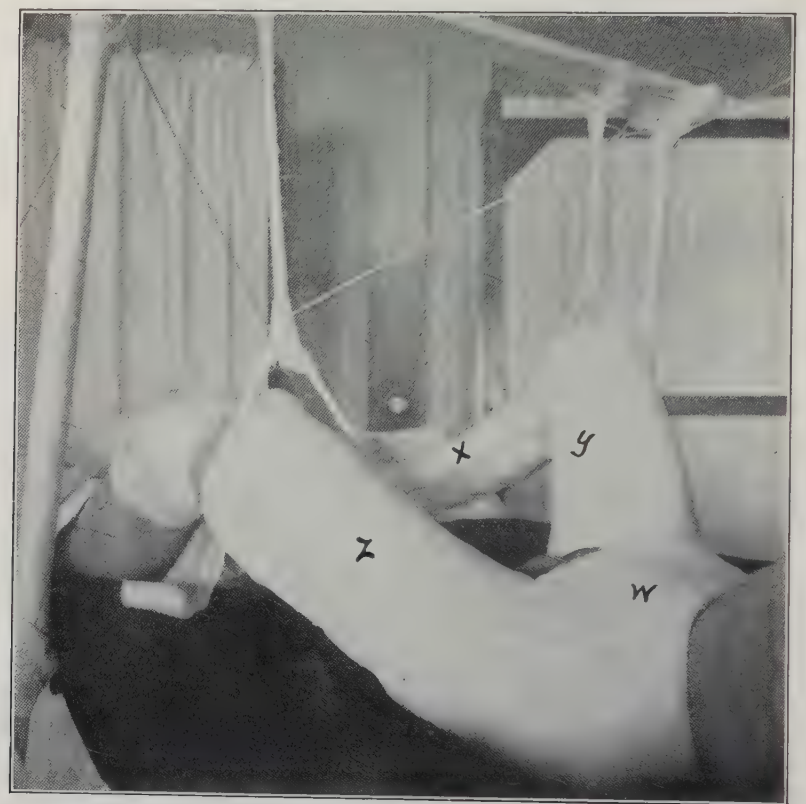

Fig. 875.—Fracture of the neck of the femur. A double spica bandage of plaster of Paris applied under an anesthetic. The thigh slightly flexed, *abducted* with *traction*. *x*, Rod of plaster holding thigh steady; *z*, splint extends to knee only; *y*, injured leg splint extends to ankle or includes whole foot; *w*, body or pelvic portion of splint. The frog spica (Straus).

of the foot of the bed, as is usual when traction is employed, improves the blood-supply of the injured part.

The normal abduction of the hip is limited by the contact of the great trochanter with the tissues above the acetabulum. When the limb is normally abducted the under part of the capsule is rendered taut and tends to retain the broken neck or head in normal relations, while the abducted position itself helps to force the broken neck more and more into its natural relations. In an impacted fracture the abducted position serves to reduce

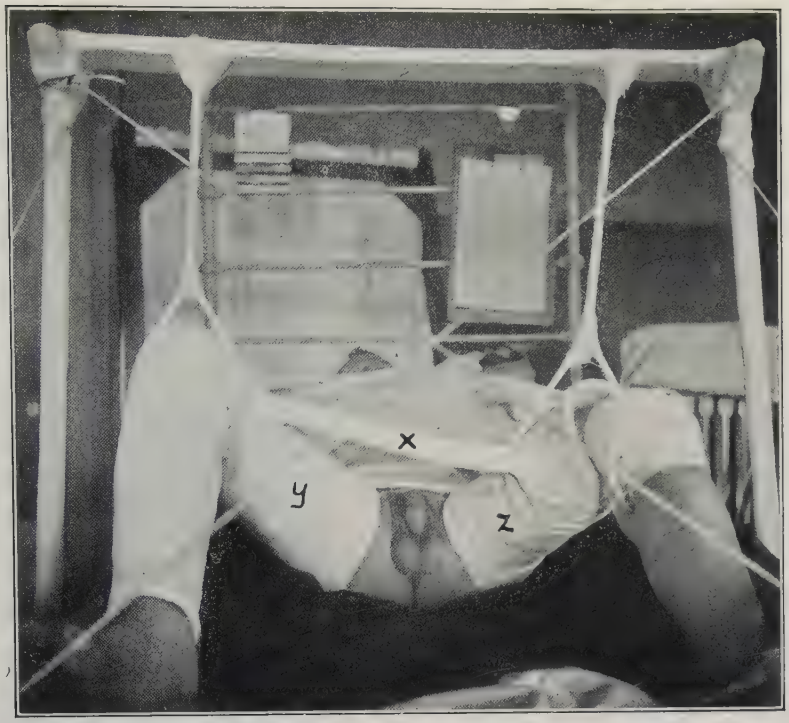

Fig. 876.—Same as Fig. 875, a front view. If the splint of plaster is carefully applied it is a most comfortable splint and not a tedious position for convalescence. The thighs cannot always be so much permanently flexed. Legs are suspended just to clear bed. The frog spica.

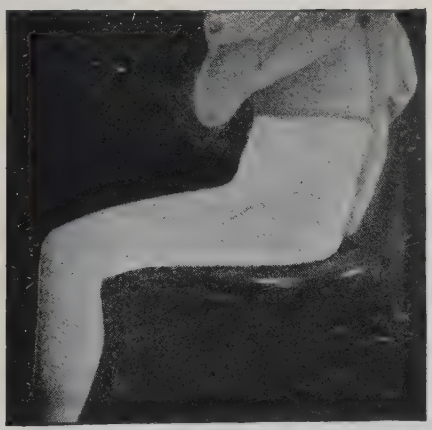

Fig. 877.—Plaster-of-Paris splint to lower extremity and pelvis with thigh and leg flexed so that in elderly people the sitting position may be used as well as the recumbent position. Very occasionally this position is desirable after fracture of the neck of the femur or impacted fracture through the femoral trochanters (after Preston and Nifong).

deformity without altogether separating the fragments and completely breaking up the impaction. In complete and unimpacted fractures the abducted position adjusts the fragments and fixes them (Figs. 867–880).

If the plaster spica has been properly applied and adjusted it is far more comfortable than any appliance that, like traction, requires rest upon the back. The patient may be turned at intervals to the side, or completely over, to relieve the pressure on the sacral region, or even moved from place to place without discomfort. Thus hypostatic congestion and bed-sores may be prevented.

The apparatus required in applying the treatment is of the simplest description and can be easily obtained or improvised. The patients are anesthetized

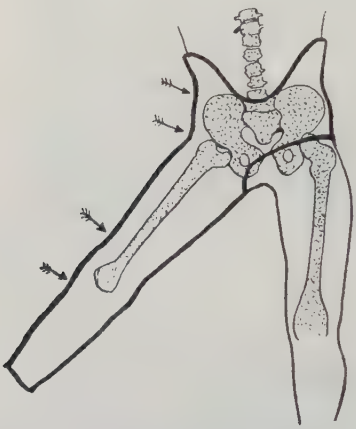

Fig. 878.—The short spica applied to fix the limb in the abducted position, showing the method of molding it about the pelvis and knee to assure fixation (Whitman).

Fig. 879.—The short (Lorenz) spica, illustrating the perineal band which prevents movement of the pelvic portion of the spica (Whitman).

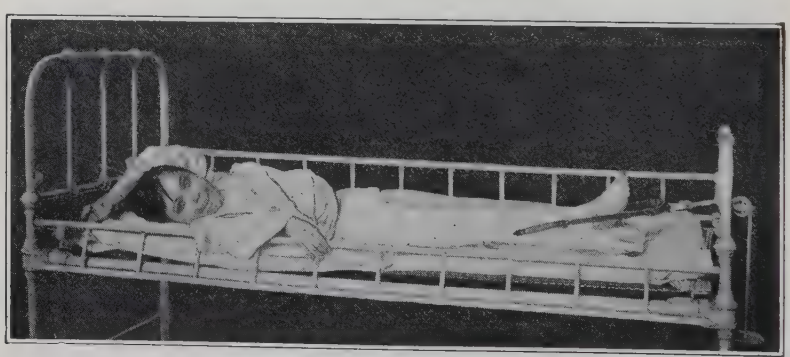

Fig. 880.—The short plaster spica combined with traction (Whitman).

to relieve discomfort and because muscular relation is essential to complete abduction. Gas and oxygen, if skilfully administered, answer the

purpose and should be comparatively free from danger even in advanced life.

If a fluoroscopic reduction of the fracture of the neck of the femur is impossible, it is absolutely essential that the attempted reduction of the femoral neck fracture should be confirmed by stereoscopic Roentgen ray. Even if the fluoroscope is used, stereoscopic plates should be taken for a record of the case. It will be rarely necessary to attempt reduction a second time. The Roentgen ray will determine this.

After-care of the Patient in Abduction Plaster Splint.—The *plaster spica* is retained as a support from eight to twelve weeks, a time sufficient, it may be assumed, to assure adhesion of the fragments as demonstrated by the Roentgen ray, but by no means a resistant union. *After its removal* the patients remain in bed preferably for several weeks for massage, passive and active movements of the joints, and re-establishment of muscular control. Several times a day the limb is drawn out by the attendant to the full limit of abduction, otherwise a gradual restriction of its range will be apparent, a clinical indication of the fact that flexion and adduction are the natural accommodations to weakness and discomfort. *Weight bearing*, therefore, should never be permitted with the possible exception of certain fractures at the base of the neck, or in childhood, for at least six months, and often only after a much longer interval, because repair is slow and because the strain is much greater than in any other situation. The indications for resumption of functional use are the situation of the fracture, the process of repair as shown by *x*-ray pictures, and, above all, by the restoration of voluntary control and free and painless active movements. Since the period of reconstruction is so prolonged, the use of a caliper hip splint which permits locomotion without direct weight bearing is desirable; otherwise, crutches must be employed.

(*b*) *Frog plaster* (Moore's method)—without attempting to modify the Whitman method. In certain cases of all first three groups there will be times when the plaster-of-Paris splint may with comfort and propriety be applied with knees and thighs flexed in the frog position (see Figs. 875–877, inclusive).

Premature weight bearing may prevent union in central neck fractures, while in those at the base of the neck it may increase deformity or stimulate excessive callous formation.

Adequate protection after union of the fracture is very important. Prolonged abstinence from full weight bearing is essential.

The overwhelming accumulation of evidence that the abduction treatment is highly efficient in the treatment of fracture of the neck of the femur in securing bony union has raised the most neglected of all fractures to the first place in the therapeutic scale. One may offer a favorable prognosis both as to life and function in about 75 per cent. of all cases treated by the abduction method if it is effectively applied.

(*c*) *Light traction* and some form of partial immobilization. Method

applicable to the few cases (Group 2) having an impacted fracture in which an anesthetic is to be avoided and the least manipulation possible made of the injured part.

Fig. 881.—Epiphyseal fracture. The apparent shortening of the neck and the loss of the prominence of the trochanter are explained by the outward rotation of the limb (Whitman).

Fig. 882.—Taken through the plaster spica after reduction. The neck fragment is now within the acetabulum; the trochanter is apposed to the side of the pelvis and symmetry is restored (Whitman).

The patient should be placed upon a comfortable, firm hair mattress. Underneath the mattress, crossing the bedstead from side to side, should be

Fig. 883.—Six months later, showing anatomical reposition. Compare with Figs. 881 and 882 (Whitman).

placed several wooden slats about 8 inches apart. These bed slats prevent sagging of the mattress and much consequent discomfort. Great caution

must be exercised that no sudden or forcible movements of the hip are made which might break up the impaction of the bone or cause unnecessary

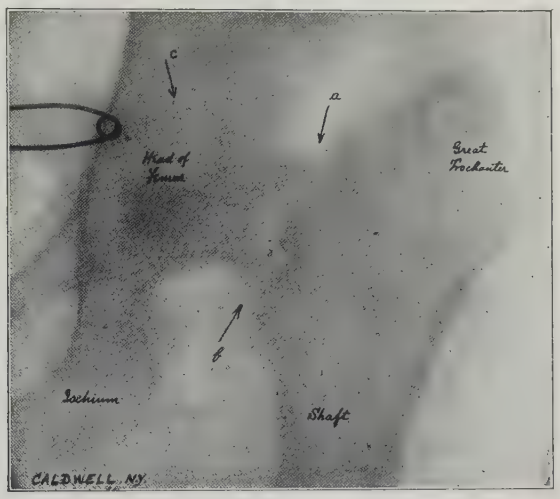

Fig. 884.—Case of Whitman. A girl sixteen years old. Injured by a fall from a carriage. Fracture of the neck of the femur. This *x*-ray was taken six months following the accident. Note that the arrows *a* and *b* point to the seat of fracture. The arrow *c* almost touches at its tip the rim of the acetabulum and the rounded head of the femur.

pain. The leg should be placed in as natural a position in extension as possible. The knee should be placed upon a pillow. Extension strips of

Fig. 885.—The Hawley frame for facilitating the application of plaster-of-Paris splint with possible abduction of thigh; used on an ordinary bed (The Kny-Scheerer Corp.).

cotton cloth should be applied to the leg and thigh as high as the perineum, and should be held to the skin by Sinclair's glue or adhesive plaster extension strips may be used. A weight of about 5 pounds should

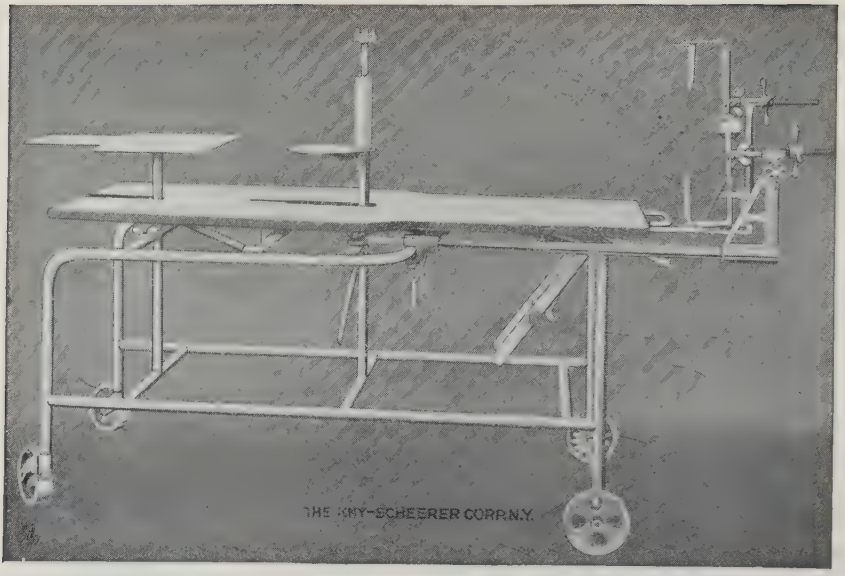

Fig. 886.—The Hawley fracture table (The Kny-Scheerer Corp.).

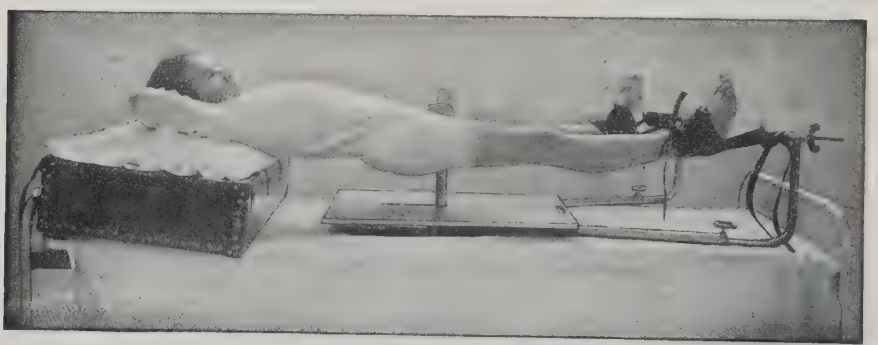

Fig. 887.—Hawley frame. Same as Fig. 885 in use. Note opportunity afforded for ready application of plaster-of-Paris splint (The Kny-Scheerer Corp.).

Fig. 888.—Showing patient lying on Hawley fracture table ready for application of plaster-of-Paris splint (The Kny-Scheerer Corp.).

be applied to the extension while the leg is gently rotated and carefully placed approximately in the normal position. The foot of the bed should be elevated to the height of 6 inches in order to secure counterextension. Long and heavy sand-bags should be placed on each side of the leg and thigh to assist the light extension in affording support and to give a sense

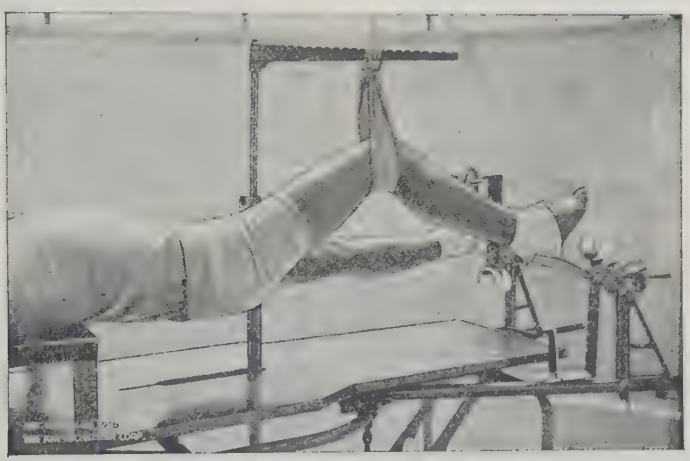

Fig. 889.—Same as Fig. 888, with flexion of thigh on body and flexion of knee (The Kny-Scheerer Corp.).

of security. The heel, as mentioned before, should be properly protected from undue pressure. The foot should be kept at a right angle with the leg. To afford still greater immobilization, if it is absolutely necessary, a long T-splint extending from below the foot to the axilla of the injured side

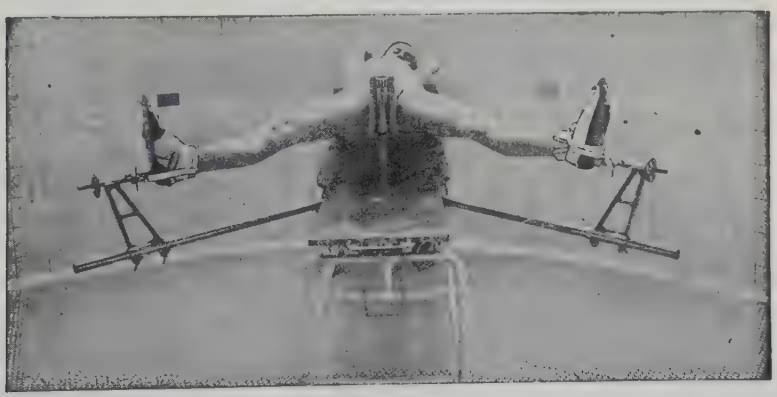

Fig. 890.—Hawley fracture table. Complete abduction of both thighs possible (The Kny-Scheerer Corp.).

may be applied by straps about the leg and a swathe about the body (see Figs. 989, 990) instead of the long T-splint. The whole lower extremity should be placed and kept in slight abduction. I have found that the application of a strap, made of duck, about the hip and pelvis is of great use. The strap is 4 or 5 inches wide and has stitched to it two pads of leather 3 or 4 inches

apart. These pads are adjusted so as to rest behind and in front of the great trochanter of the injured hip.

The posterior pad attempts to accomplish what the molding of the plaster-of-Paris spica does in the Whitman treatment—it supports the trochanter of the femur, preventing a falling or dropping or rolling of the femur backward and outward.

The strap exerts firm lateral direct pressure on the trochanters. This strap, together with the light extension in an abducted position, will often be found of service. The skin over the trochanter and pelvis receiving the pressure must be cared for with bathing, alcohol, and powder. This old extension method will require most unusual care on the part of nurse and surgeon. It is very rarely applicable and is to be avoided whenever other methods can be used.

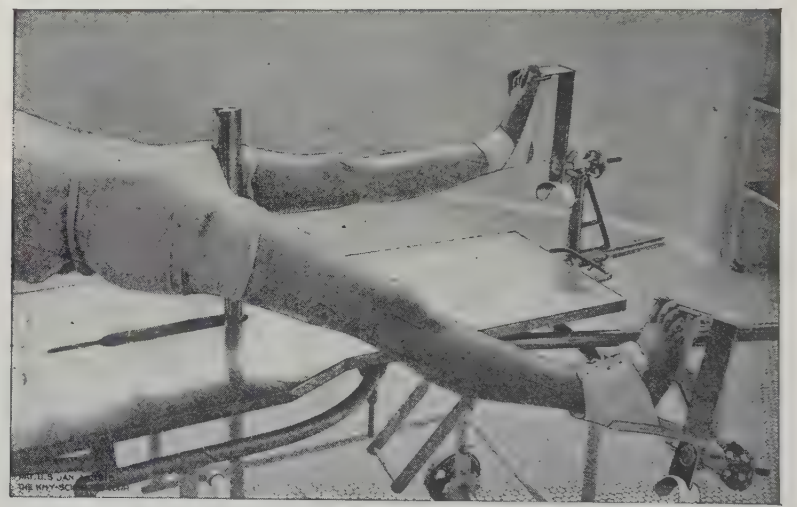

Fig. 891.—Showing the possibility of securing hyperextension of the hip-joint with abduction of the thigh and inversion of the foot on the Hawley table (The Kny-Scheerer Corp.).

The **Maxwell-Ruth plan,** a position and traction method for treating femoral neck fracture, is as follows: (*a*) Flexing the thigh at right angles to the trunk, (*b*) an outward traction upon the upper end of the femur in order to correct the displacement in fracture of the neck, (*c*) the adjustment of a continuous lateral traction, (*d*) and direct longitudinal traction by Buck's extension. This plan of Maxwell for fracture of the neck of the femur is not to be recommended as a routine procedure.

This method uses the capsular ligament as a splint by making the capsule tense through the application of traction in two directions. It is not necessary to use an anesthetic in applying the Maxwell-Ruth method of treatment.

After-care of the Simple Traction Method.—The general care of the patient should be as outlined previously. He should be kept quiet in bed

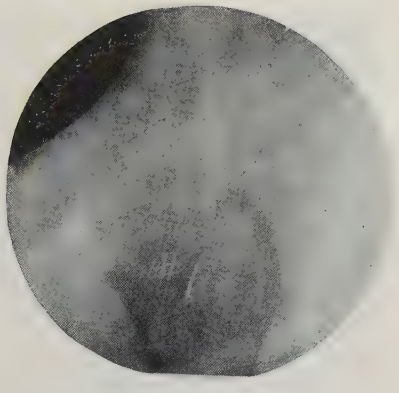

Fig. 892.—Miss I. M., May 14, 1923. Central fracture of neck of femur. Following attempted reduction in the abducted position (Campbell).

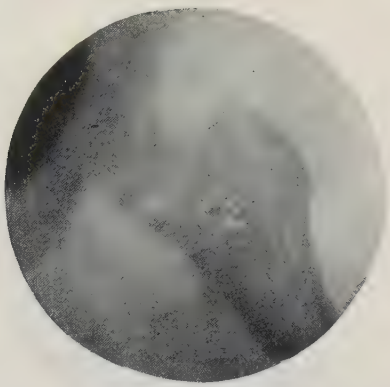

Fig. 893.—Miss I. M., May 14, 1923. After artificial impaction (Campbell).

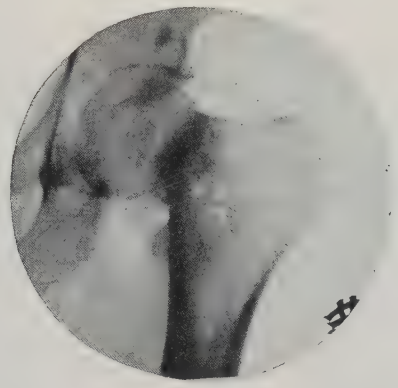

Fig. 894.—Miss I. M., October 30, 1924. Solid bony union after artificial impaction. One year, five and a half months after accident (Campbell).

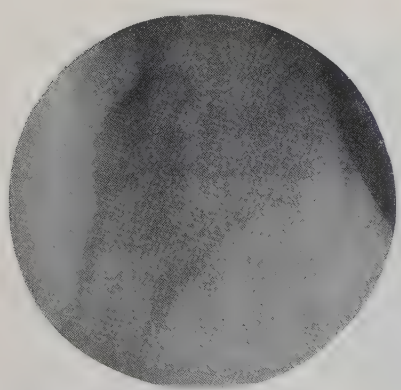

Fig. 895.—Miss E. G. C., November 11, 1921. Central fracture of neck of femur. Placed in abducted position (Campbell).

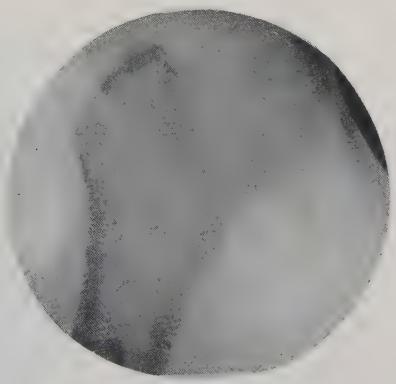

Fig. 896.—Miss E. G. C., November 11, 1921. After artificial impaction (Campbell).

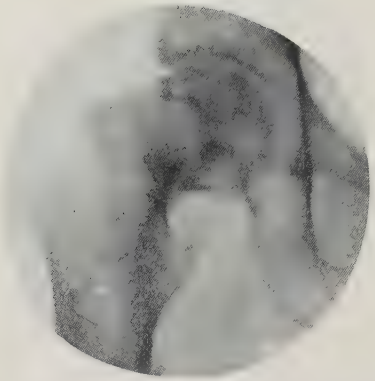

Fig. 897.—Miss E. G. C., January 27, 1924. Solid bony union (Campbell).

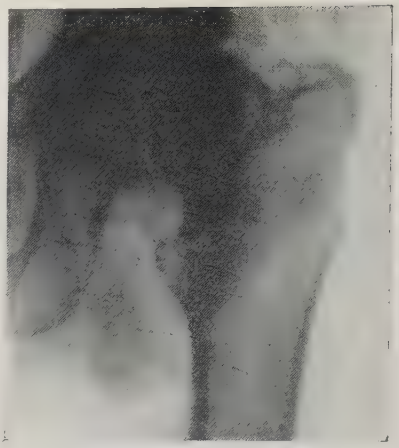

Fig. 898.—Miss E. G. C., January 3, 1925. Solid bony union three years after the injury (Campbell).

Fig. 899.—Mrs. J. L. E., July 3, 1922. Central fracture of neck of femur (Campbell).

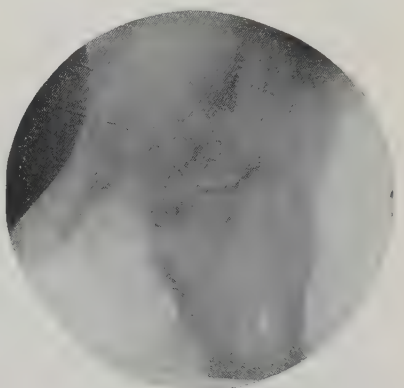

Fig. 900.—Mrs. J. L. E., July 3, 1922. Following reduction and artificial impaction (Campbell).

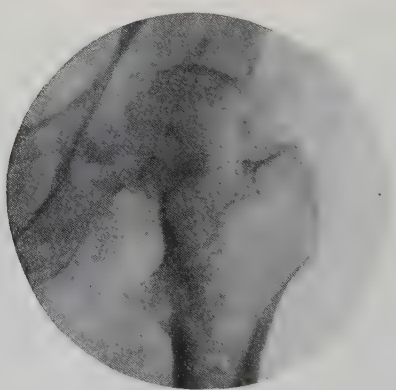

Fig. 901.—Mrs. J. L. E., April 5, 1923. Solid bony union. Note bone impaction after nine months (Campbell).

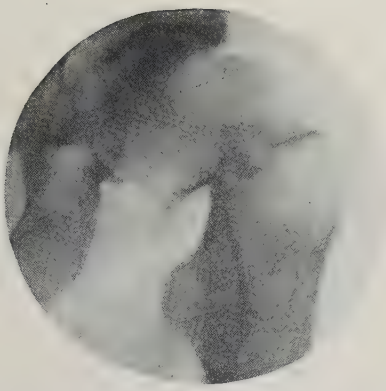

Fig. 902.—Mr. C. L. P., June 3, 1924. Central fracture of the neck of the femur (Campbell).

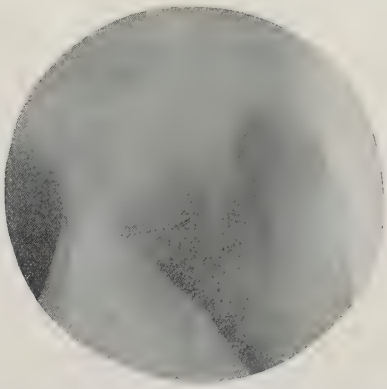

Fig. 903.—Mr. C. L. P., June 3, 1924. After reduction in abducted position. Note bony apposition and contact (Campbell).

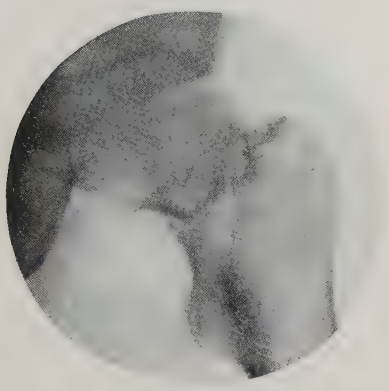

Fig. 904.—Mr. C. L. P., July 28, 1924. After removal of plaster spica. Note solid bony union and impaction (Campbell).

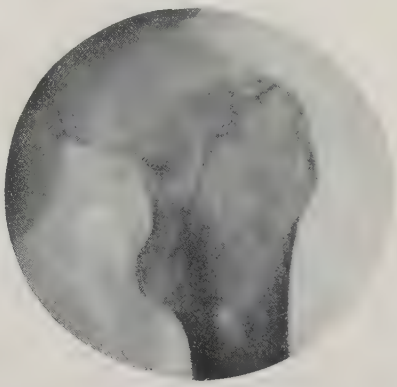

Fig. 905.—Mr. C. L. P., November 21, 1924. Almost six months since the accident and four months since retentive apparatus was removed. Note artificial impaction. Compare with Fig. 906, showing normal opposite uninjured hip. Note angle of head and neck (Campbell).

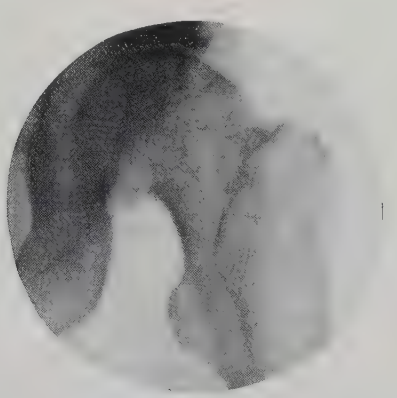

Fig. 906.—Mr. C. L. P. *x*-Ray of uninjured femur for comparison with injured side. Compare with result of fracture in Fig. 905. Note angle of head and neck (Campbell).

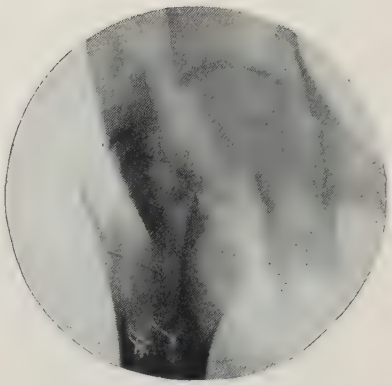

Fig. 907.—Mrs. N C. C., October 3, 1921. Central fracture of neck of femur. Compare with x-ray of uninjured hip, Fig. 912 (Campbell).

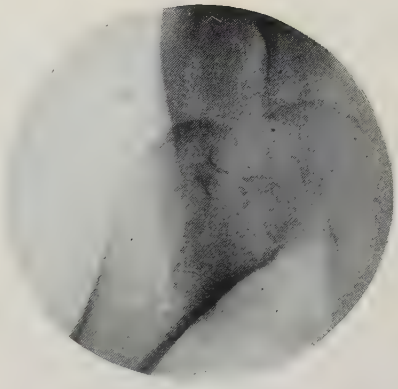

Fig. 908.—Mrs. N. C. C., October 3, 1921. Reduction in abducted position. Note bone contact and relative position of head and neck (Campbell).

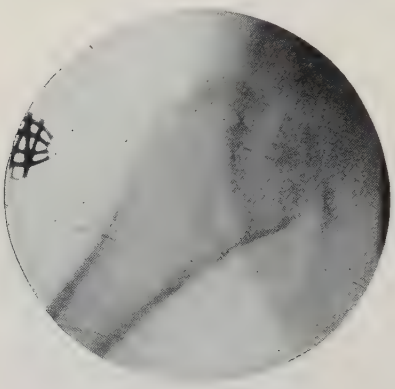

Fig. 909.—Mrs. N. C. C., October 3, 1921. After artificial impaction. Note closer approximation of fragments than in Fig. 908 (Campbell).

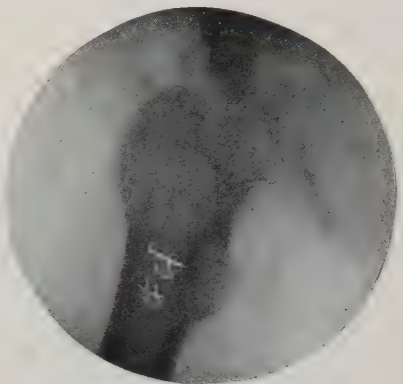

Fig. 910.—Mrs. N. C. C., January 4, 1922. After removal of plaster spica splint. Note bony union with artificial impaction maintained (Campbell).

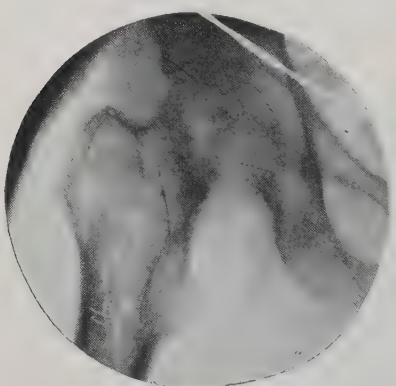

Fig. 911.—Mrs. N. C. C., February 10, 1922, four months after accident. Note solid bony union. Result December, 1924, function of hip perfect. Bony findings essentially the same as in this plate. Compare Fig. 912 (Campbell).

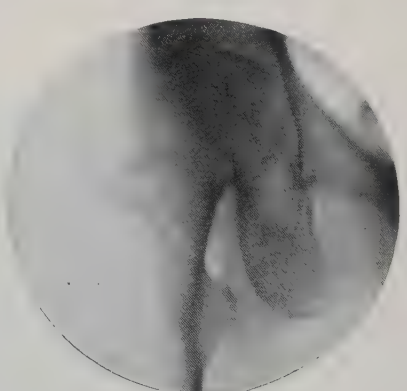

Fig. 912.—Mrs. N. C. C. October, 1921. Uninjured hip. Compare this with injured hip, Fig. 911. Note upper and lower lines of neck and relation of head to neck.

for about six weeks. During the second week he may be bolstered up on pillows to the half-sitting position. Ordinarily, the extension may be removed during the fourth week. The patient may then be lifted to another bed or divan and be rolled into an adjoining room. In this change the thigh should be supported by sand-bags. The patient may be up in a wheel-chair after the first two months with the knee straight or flexed. He may use crutches and a high shoe upon the well foot, not bearing any weight upon the injured hip for about six months. He should be protected by a hip-splint as mentioned under the abduction treatment. He should not bear weight upon the hip without the assistance of crutches and splint for about six months to a year.

At the end of a year he may be walking with one cane. The foregoing is the course of a case treated according to the old-time simple extension or partial immobilization method. It is a matter of common observation that some apparently impacted hips recover with fairly useful limbs with this treatment. Apparently impacted hips are known to have recovered with useful limbs without any medical or surgical advice or treatment, the fracture having been thought at the time of injury in the absence of marked deformity to be a severe contusion, which would be all right in time. These cases have occurred both among adults and children.

The accumulating results of union of transcervical fractures of the femur are instructive. A certain proportion of cases fail to unite under apparently favorable conditions. The following individuals report results:

Waldenström[1] reports 103 cases of intracapsular fracture; 50 over seventy years of age had bony union, *i. e.*, 55 per cent.

Campbell's[2] cases secured 89 per cent. bony union.

Portwich[3] treated 51 cases of transcervical fracture. Thirty-seven treated by different methods obtained satisfactory results in 33 per cent., but bony union and full function in but 5.4 per cent. Ten treated by the abduction method gave satisfactory results in 78 per cent., and anatomical and functional cure in 70 per cent.

W. C. White[4] secured in intracapsular cases 50 per cent. bony union.

O. Löfberg[5] treated 70 cases by the abduction method, with bony union in 56 per cent.

Uno Lindberg[5] treated 5 cases and secured bony union in 60 per cent.

(*d*) **The Bradford Abduction Splint.**—The use of plaster of Paris for the long spica in fractures of the hip has advantages. It is always available, it is easily applied, the method is of universal applicability. It can be used in the aged, it does immobilize, it will always be the splint for emergency treatment and the permanent splint for most surgeons to use. On the other

[1] Waldenström, Journal de Chir., August, 1924.

[2] Campbell, Annals of Surgery, November, 1919; Jour. Amer. Med. Assoc., October 20, 1923.

[3] Portwich, Deutch. Zeits. f. Chir., April, 1925.

[4] White, New York State Journal Med., October 15, 1925.

[5] Löfberg, Acta Chir. Scand., July 12, 1924.

hand, one advance in fracture treatment in recent days is the recognition of the use of means for retaining fractures which permits of muscle functioning and access to the parts involved.

The Bradford splint, a modified Thomas splint, is a most desirable addition to the armamentarium of the surgeon for immobilizing the hip in a position of abduction, extension, and rotation inward and at the same time allowing access to the part and permitting early locomotion.

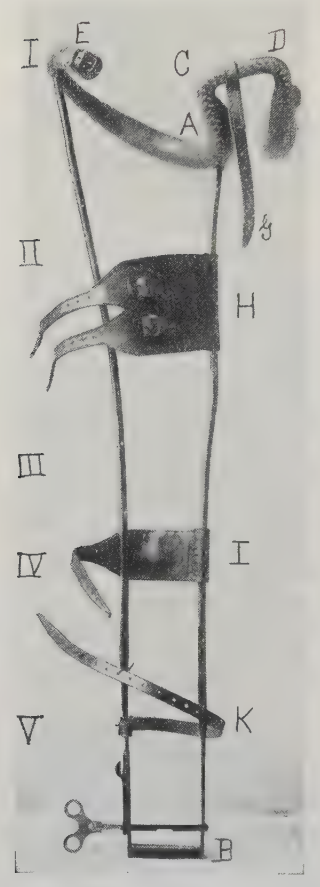

Fig. 913.—Bradford abduction traction splint for right hip fracture. Anterior view. Note key for ratchet. Straps for thigh (H), calf (I), and ankle (K). (Photos by Soutter.)

Fig. 914.—Bradford abduction traction splint. Posterior view. Note key for ratchet. (Photos by Soutter.)

Patients in very considerable number with fracture of the neck of the femur have been treated far more comfortably in this splint and with the same satisfactory anatomical results as in plaster of Paris.

Moreover, with the abduction splint movement of the patient without assistance is possible, general muscular atrophy is minimized, general circulatory conditions are improved, the entire skin surface can receive daily

attention. At the end of the second week the patient is helped in walking, wearing a low lift on the shoe of the uninjured leg, so that the splint clears the floor. At the end of eight or ten weeks immobilization is omitted. The hip is then protected by a hip splint only, without abduction. At the end of five or six months following fracture patients are walking protected,

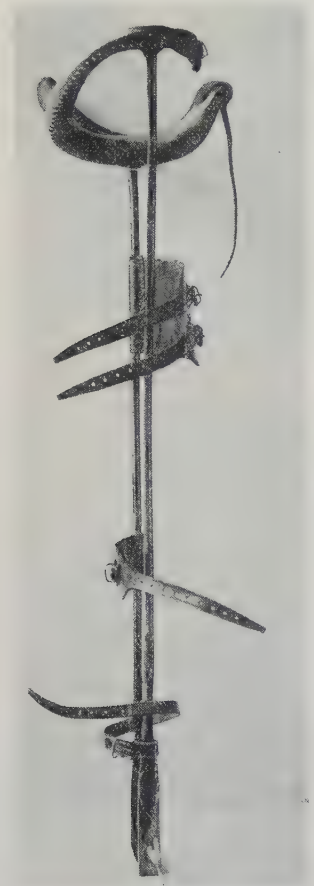

Fig. 915.—Bradford abduction traction splint. External lateral view. (Photos by Soutter.)

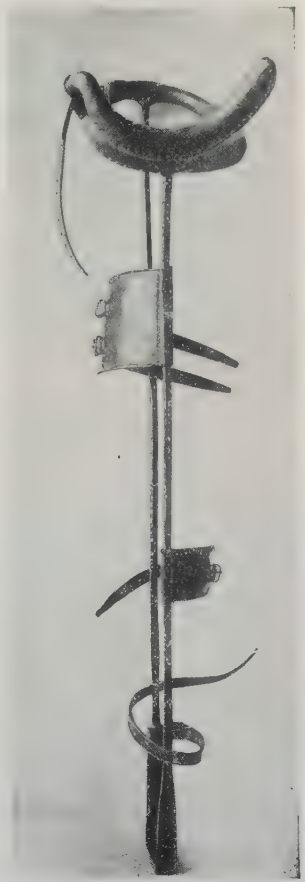

Fig. 916.—Bradford abduction traction splint. Internal lateral view. (Photos by Soutter.)

with and without a cane, and without great knee stiffness and with splendid muscle tone.

The Bradford splint is not advocated for general use. It can only serve the man skilled in measuring, applying, and caring for it. It must be made for each patient.

It is presented here as having more ideally cared for this distressing injury than any other apparatus thus far used. The time required for treatment is reduced to a minimum. The general good condition of the patient following such a fracture is quite in contrast to that seen as a routine from the prolonged plaster-of-Paris splint.

The illustrations show the splint and its use.

Measurements for the Bradford Abduction Splint.—Length A–B from the tuberosity of the ischium to the sole of the foot, plus $2\frac{1}{2}$ inches (see Fig. 913).

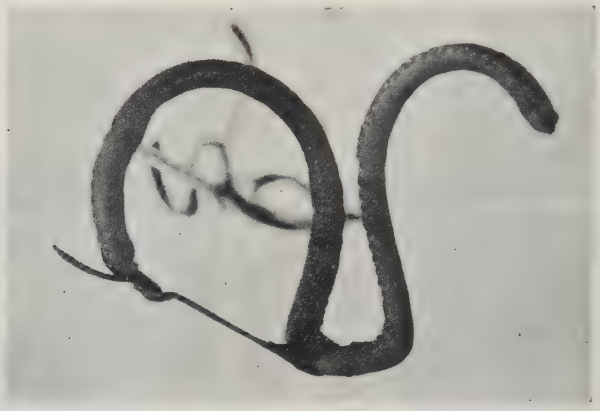

Fig. 917.—Bradford abduction splint. View from above of the two thigh bands. (Photos by Soutter.)

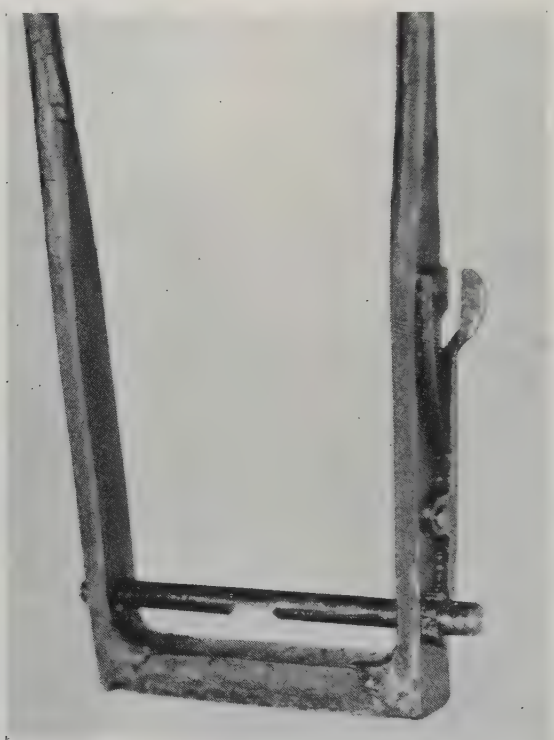

Fig. 918.—Details of the lower end of the splint. Note ratchet for traction. (Photos by Soutter.)

Measure oblique (45 degrees with upright) circumference of groin skin, I.
The mechanic is instructed to allow for the leather padding.
The front of the ring is to be open (E, C) $2\frac{1}{2}$ inches.

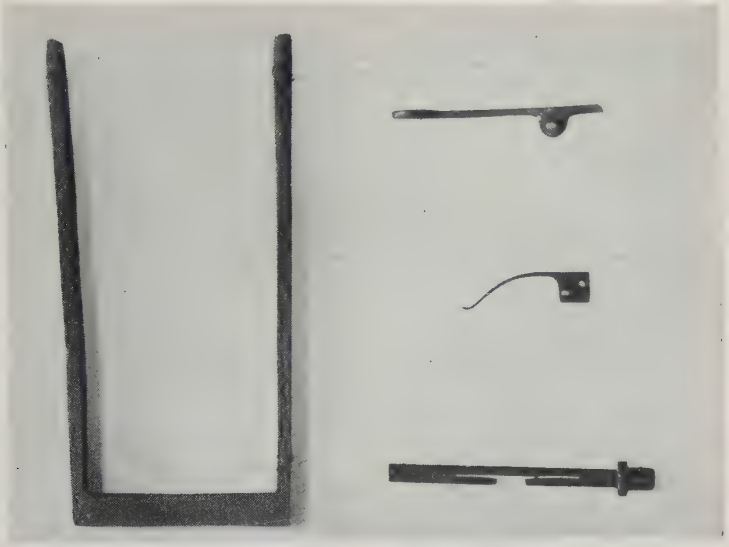

Fig. 919.—Note detailed parts of the ratchet. (Photos by Soutter.)

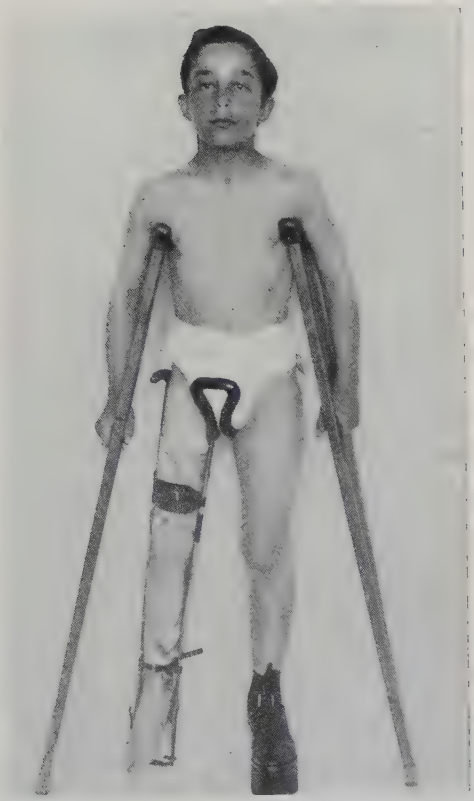

Fig. 920.—A Bradford abduction splint applied, showing patient wearing high soled shoe; crutches. Splint useful in fracture of the femoral neck in adults (see Fig. 921) (L. S. Kemp).

Fig. 921.—Case sixty-three years old (see Fig. 922). Fracture of the neck of the femur. Bradford traction and abduction splint used in treatment. Note splint in place—high sole on opposite foot (L. S. Kemp).

Fig. 922.

Fig. 923.

Figs. 922, 923.—Case sixty-three years old (see Fig. 921). Fracture of the neck of the right femur. Treated by the Bradford abduction splint. Note result in flexion at hip and stability in walking. Sat up in bed after one week. Walking frame after three weeks. Walking with crutches after seven weeks. Union solid in nine weeks. Splint removed in bed after ten weeks. Walked with only crutch support after twelve weeks. No shortening. All motions practically normal. No limp. Resumed original occupation, matron of a large hall (Kemp).

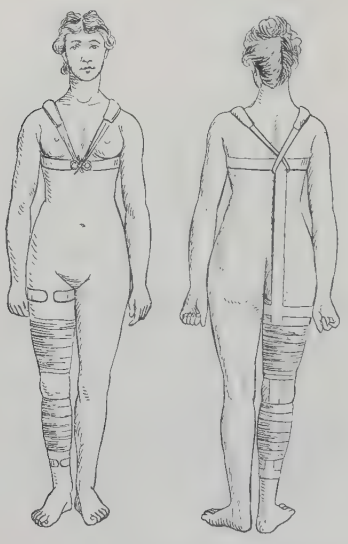

Fig. 924.—The old Thomas single hip-splint in position. Historically interesting and suggestive (Ridlon).

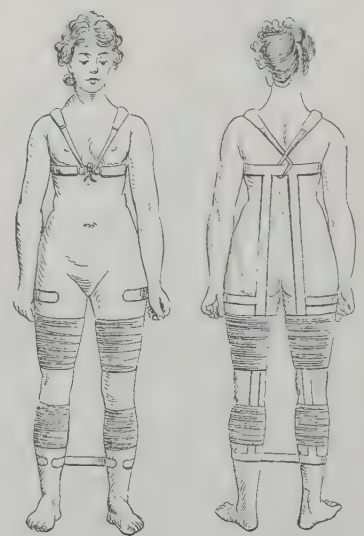

Fig. 925.—The old Thomas double hip-splint in position (Ridlon).

A buckle is placed at E and a corresponding strap at C.

Measure the skin circumference at II of the middle of the thigh, III at the knee, IV at the calf of the leg, V over the ankle-joint.

Take a tracing of the both sides of the whole length of the lower limb.

Mark on this tracing the level of the sole of the foot, the ankle-joint, and the knee-joint. The anteriorly placed thigh band (H) is made of leather.

The posteriorly placed calf band (I) is made of leather.

The strap (K) is made narrow to encircle the ankle a bit loosely. An extension foot-piece may be added to this splint if it is thought desirable.

The abduction arm should be long enough so that the end does not press unduly into the buttock when the patient is seated.

(*e*) **Artificial Impaction of the Hip.**—Cotton has made a distinctly definite and helpful contribution to the treatment of fracture of the femoral neck. The method produces an artificial delayed impaction which simulates that which very occasionally occurs at the time of the accident.

The method is applicable to so-called loose fractures unreduced, especially after slight delay in initial treatment. Obviously it is not to be used in long non-union cases. It has been used successfully ten weeks after the accident.

Cotton has extended successfully the application of artificial impaction to a few cases, seven weeks and ten weeks after injury, thus demonstrating by the results that the reparative process may be at times, but not always, stimulated by artificial impaction at these late dates.

If this method is ultimately applicable to old ununited cases without great absorption of the neck, it will be a splendid addition to the surgeon's resources and will avoid in some cases the major operative osteoplastic procedures now used for ununited hip fractures.

Operation of Artificial Impaction.—The operation should be done always under a general anesthetic.

1. The patient is placed on a fracture table (Hawley). Traction is made upon the injured limb until the length of the two limbs is essentially the same. The limb is rotated inward, the foot and toes being inverted.

2. A pad of a double layer of saddler's felt is placed over the great trochanter of the injured femur. The sound side of the pelvis is forcibly held braced by an assistant.

3. The surgeon strikes a heavy following blow with a maul or heavy wooden mallet ($8\frac{1}{2}$ pounds) on the padded trochanter; this blow is repeated, if necessary, until he definitely feels something yield beyond the mallet. After this occurs it will be found that the leg no longer rolls loosely into a position of eversion, but remains more secure. The appearances become those of an impacted fracture of the neck of the femur.

4. The surgeon then has to deal with an impacted fracture of the hip. A plaster spica to the lower extremity is applied with the limb in abduction and internal rotation, sometimes a double plaster spica is applied, including, however, only the thigh of the uninjured side.

Abduction prevents adductor contracture often troublesome in the period of re-establishment of function. It neutralizes the tendency to coxa

vara from muscle pull and is a more convenient position for the bed-care of the patient (Cotton).

5. *After-care.*—About eight weeks of absolute immobilization followed by an ambulatory splint without weight bearing; and later (after three months) protected weight bearing; and still later (after six months) full weight bearing. In a very heavy person the time for full weight bearing should naturally be postponed. After six months Cotton says the question is one of use, of regaining strength, and losing the limp.

Campbell, of Memphis, Tenn., has used the method of artificial impaction for the past five years. He has employed this method as a routine procedure in all complete central fractures of the neck of the femur. After artificial impaction the limb is placed in the abducted position in a plaster-of-Paris spica splint.

I herewith reproduce from the Campbell Clinic certain *x*-ray records of unselected cases. These cases are seen, then, after the accident, following the artificial impaction and at varying times subsequently (see Figs. 895–912).

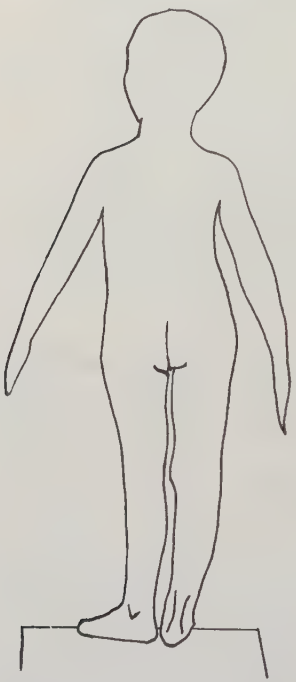

Fig. 926.—Tracing of photograph of patient (see skiagram, Fig. 927) four years after fracture of the left femoral neck, showing the shortening and turning out of the leg (after Whitman).

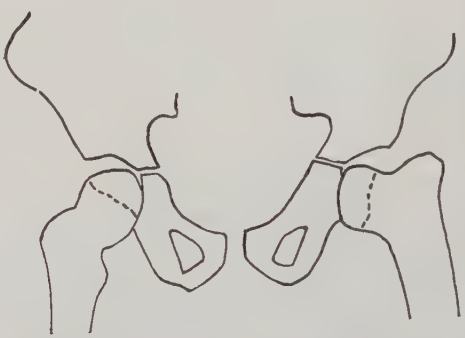

Fig. 927.—Skiagram tracing of patient two and a half years of age, after the accident, illustrating the deformity of the neck and of the upper extremity of the shaft, also the elevation of the pelvis on the affected side (after Whitman).

The fact that artificial impaction can be secured uniformly without difficulty is here demonstrated and amply confirms Cotton's original contention. Solid union by bone is likewise demonstrated in these artificially impacted cases.

The ability of this bony union to support the body weight without materially yielding after several years of normal weight bearing is demonstrated in certain of these artificially impacted and abducted hips.

The Campbell evidence of the efficacy of the Cotton artificial impaction combined with the position of abduction in securing bony union of the central

loose fracture of the neck of the femur is positive and unmistakable (see Figs. 895–912).

Fracture of the Neck of the Femur in Childhood.—Whitman has called especial attention to this fracture. The anatomical proof of the existence of fracture of the neck of the femur in childhood has been furnished by the specimens of Bolton, Meyers and Starr, and by many *x*-rays. The fracture occurs after traumatism to the hip probably more frequently than separation of the upper femoral epiphysis. It is not so uncommon an acci-

Fig. 928.—Tracing of photograph of patient eight years old, some years after a fracture of the neck of the right femur, showing great projection and elevation of the trochanter, made more apparent by flexing the thigh and leg (Whitman).

dent as has been supposed. The fracture is probably impacted or greenstick. The clinical picture of fracture of the neck of the femur in childhood differs greatly from that furnished by a similar injury in old age. In the first instance a healthy child falls from a height, and presents a shortening of the thigh of from $\frac{1}{2}$ to $\frac{3}{4}$ inch. There are slight outward rotation of the leg and limitation of motion and slight discomfort in the hip. The child may walk about after a few days with but a little lameness to suggest that any injury has been received. The child recovers with a limp. Months or years later signs of coxa vara appear. In childhood a rather severe injury is followed by immediate symptoms, and later by great disability. On the other hand,

in old age a trivial injury is followed by immediate and complete disability. It is often overlooked in the child and is treated for a contusion or sprain of the hip.

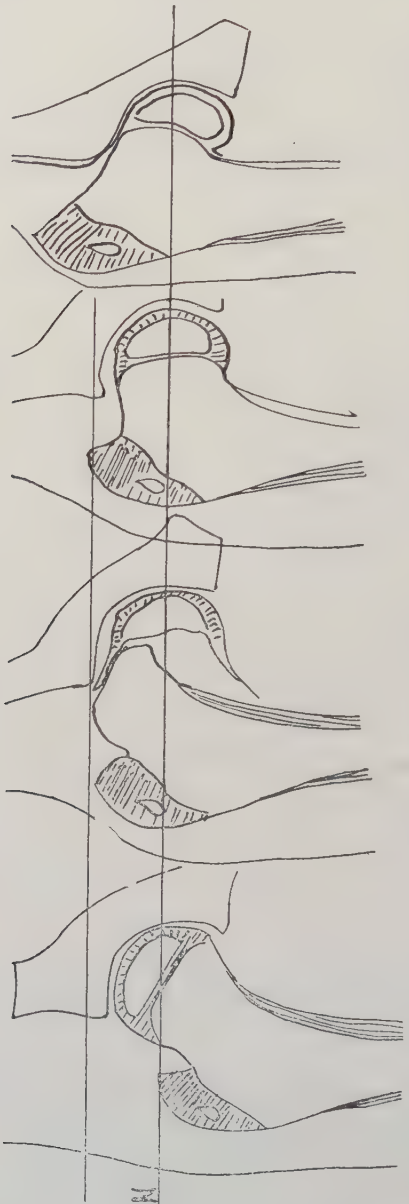

Fig. 929.—Upper extremity of the femur. Exact size at the age of five years, showing the epiphysis of the head and trochanter and the relation of the trochanter to Nélaton's line, *N*. The shaded area represents the cartilage (after Whitman).

Fig. 930.—A scheme to represent epiphyseal disjunction, showing the separation of fragments necessary to account for upward displacement of the trochanter to the extent of ¾ inch (after Whitman).

Fig 931.—A scheme to illustrate fracture and depression of the neck of the femur and consequent elevation of the trochanter, also the limitation of the range of abduction of the limb that must result (after Whitman)

Fig. 932.—A scheme to illustrate further depression of the neck and its effect in causing permanent adduction of the thigh (after Whitman).

The immediate result, however, is extremely good even without more than bed treatment, but the ultimate result after several months or years may be disastrous because of the disability due to a gradually increasing bending of the femoral neck. The late result of fracture of the femoral neck in childhood resembles hip disease in the limp, slight pain, shortening,

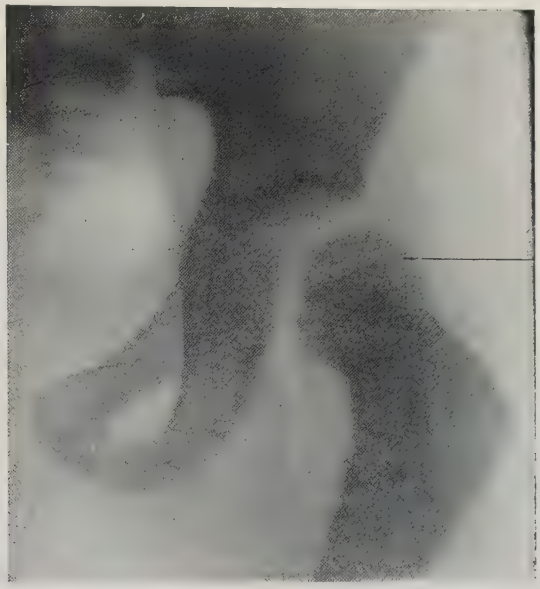

Fig. 933.—Separation of the upper epiphysis of the femur. Note epiphysis separated and displaced so as to rotate the femur inward, corresponding to the photograph of the attitude of this patient (see Fig. 935). Absence of the lesser trochanter demonstrates the rotation of femur inward (Mumford). (See Fig. 934.)

Fig. 934.—Separation of the upper epiphysis of the femur. After reduction by traction. Note that the femoral epiphysis is in its normal place.

deformity, and limitation of motion present. Care must be taken not to confound the two conditions. These later stages of fracture are to be treated by rest to the joint. All body weight and the jar of walking are to be removed by a properly fitting hip-splint with traction. Refracture and oper

ative measures are to be seriously entertained, as in other forms of coxa vara, particularly if the disability is great or is increasing (see Figs. 928, 929–932, inclusive).

The treatment of a fresh greenstick or impacted fracture of the hip in children should be by rest on the back in bed and moderate traction and immobilization of the hip and thigh and body. If there be deformity (shortening, eversion, or inversion) then the forcible abduction and plaster-of-Paris immobilization are required as in adults. After a month the child may be allowed up, wearing a traction hip-splint for several months until union is so firm that the danger from coxa vara is practically eliminated. A light plaster-of-Paris spica bandage from calf to axilla will maintain immobility after the splint is omitted.

Fig. 935.—Separation of the upper femoral epiphysis in a child (see Figs. 933, 934). Note the deformity as that of a dislocation of the hip on the dorsum of the ilium. Flexed and adducted thigh, flexed knee.

Adolescent hip injury in 50 per cent. is a slipped epiphysis (Key) due to trauma to a diseased epiphyseal line. Replace by Whitman treatment or by operation (Wilson[1]).

(*f*) **Operative Treatment.**—In any ununited fracture of the neck of the femur the object of treatment is to place freshened bony surfaces in firm contact and maintain this bony apposition until union has occurred. The Brackett operation does this par excellence. The failure of the wire nail alone lay in the fact that the bony surfaces were not materially freshened.

The treatment of ununited fracture of the neck of the femur is a complicated problem. Many factors enter into a decision in an individual case: The general condition of the patient. The social status of the individual. The amount of moving about that the old person desires to make eventually in carrying on his daily routine. There are certain individuals in whom it is best to simply adjust a carefully fitted pelvic and thigh support. Sufficient protection is thus afforded to enable the patient to move about with a cane or a crutch in comparative comfort. If operation is indicated, I believe the Brackett operation is best suited to certain cases and that the Whitman operation is suited to certain other cases. I think the wisdom of a bone-grafting operation does not obtain as a routine procedure. It is to be used with great discretion and judgment. (See page 841.)

[1] P. D. Wilson, Jour. Amer. Med. Assoc., Nov. 29, 1924, vol. 83, p. 1749.

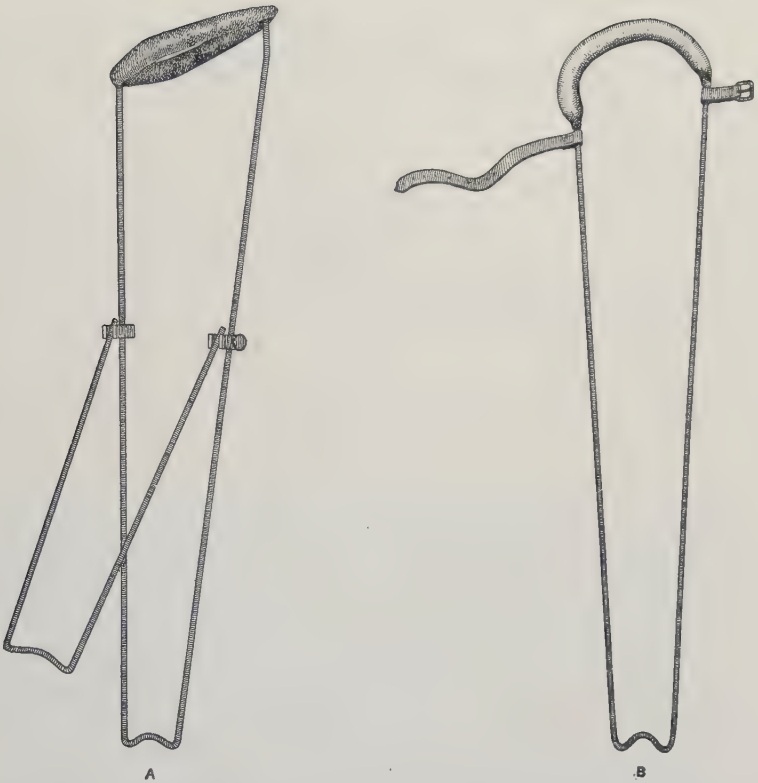

Fig. 936.—A, Thomas traction thigh and leg splint with Pearson's supplementary leg piece attached. (See Fig. 943.) B, Thomas' hinged half-ring traction thigh and leg splint. (Blake-Keller.)

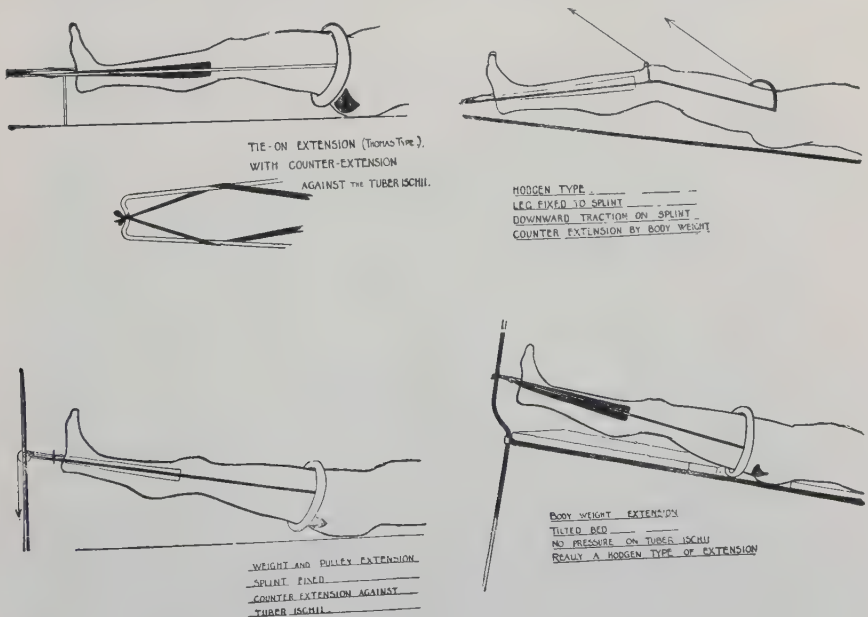

Fig. 937.—Various methods of using the Thomas and the Hodgen splints (Pearson and Drummond).

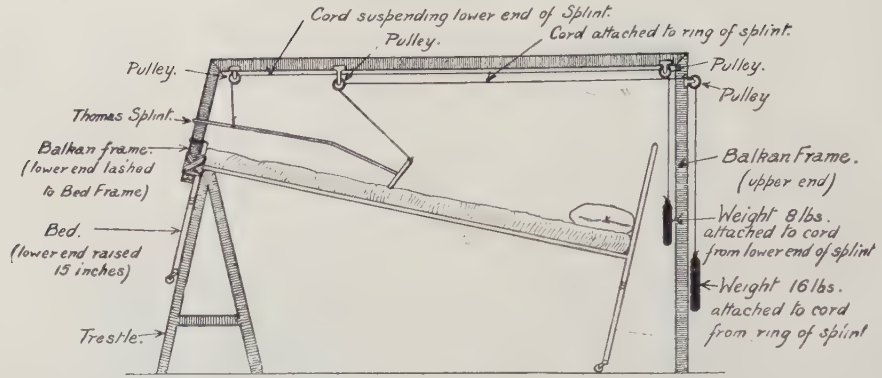

Fig. 938.—The principles involved in the application of a Hodgen plint in cases of fracture of the lower extremity (H. Winnett Orr).

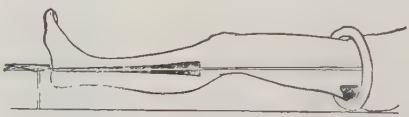

Fig. 939.—The ordinary cause of pressure sores: the ring has slipped up past the tuberosity and is nipped between the bone and the bed (Pearson and Drummond).

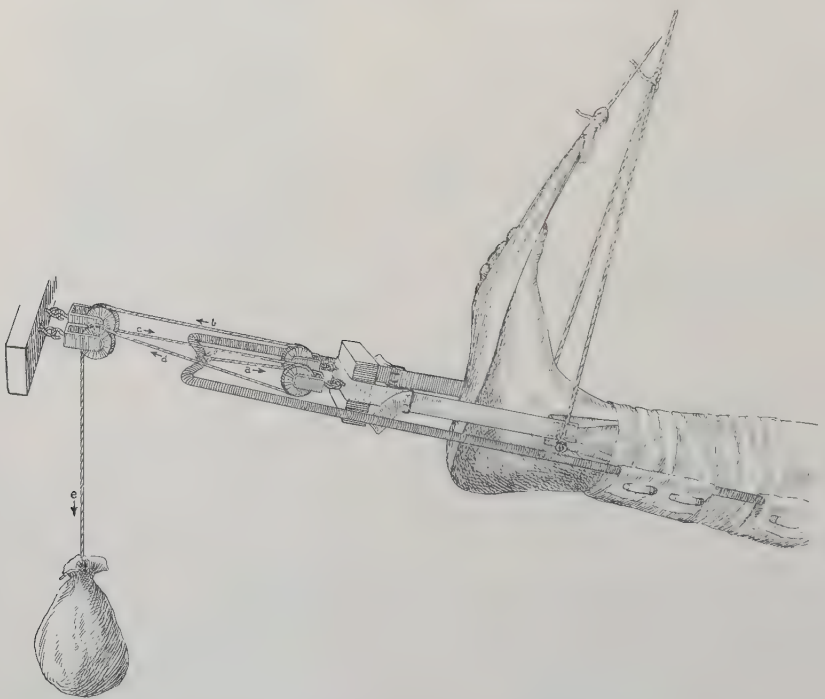

Fig. 940.—Details of method of installing fractional traction for fractures of the leg or femur in order to diminish the upward thrust of the Thomas splint, and yet obtain enough to keep the splint in place against the ischium. As drawn with four pulleys the upward thrust is one-fourth of the traction weight. With two pulleys it would be one-half. Observe also the position of the band glued to the sole of the foot to prevent foot-drop. It passes up along the inner border of the great toe, thus causing a slight outward rotation of the leg which is necessary in treating some fractures of the femur (Blake).

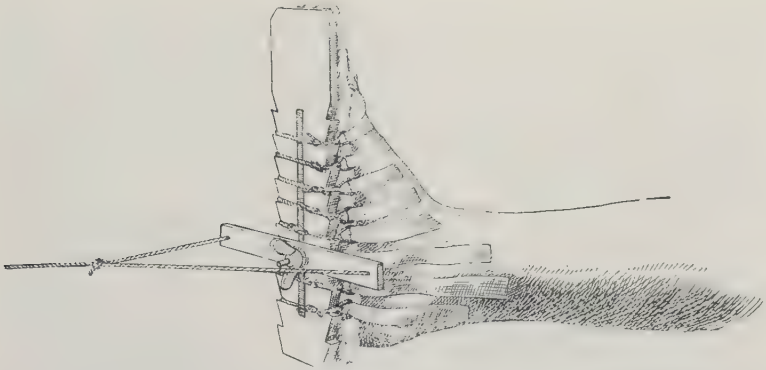

Fig. 941.—Sinclair foot board. Strips to which curtain rings bent into the shape of a triangle have been attached are glued to the sides of the foot as shown, and must not cross the dorsum. The padded board is attached to the foot by strings attached to the rings and tied under the board (Blake).

Fig. 942.—Suspension of the foot by a bandage glued on to the sole of the foot. Note the bare dorsum of the foot and the exposed region of the tendo achillis (Pearson and Drummond).

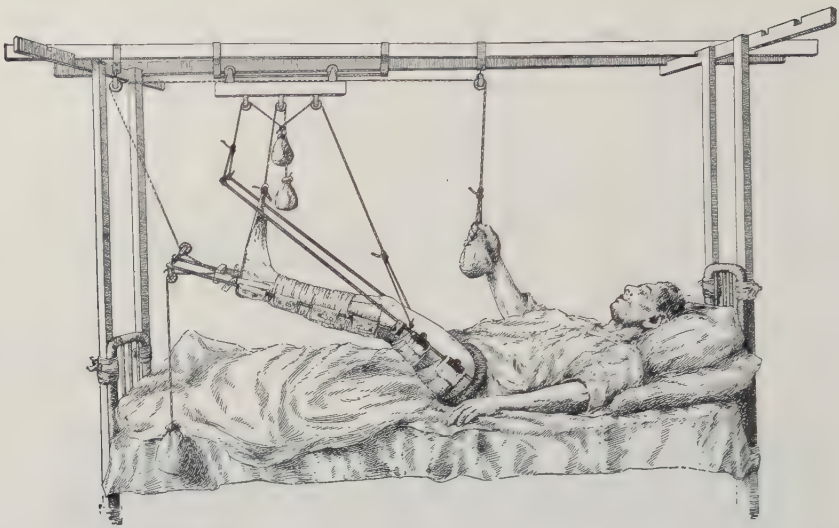

Fig. 943.—Application of the method devised by Dr. R. T. Knight for mobilizing the knee in fractures of the femur when using skin traction and the Pearson accessory leg piece. The sum of the two weights should equal the traction desired. The weight in the hand plus the weight to overcome foot-drop should counterbalance the other traction weight and the weight of the leg. The patient carries out the motions himself. With skin traction thus applied the active and passive motions should not be commenced until there is a beginning union. With skeletal traction applied by tongs directly to the distal fragment traction is made in the line of the main splint by a cord passing over a pulley on a cross-piece on the suspension frame, and there is only need of the weight passing to the hand, which together with the drop-foot weight should counterbalance the weight of the leg. Active and passive motion with the tongs applied may be instituted before union has commenced (Blake).

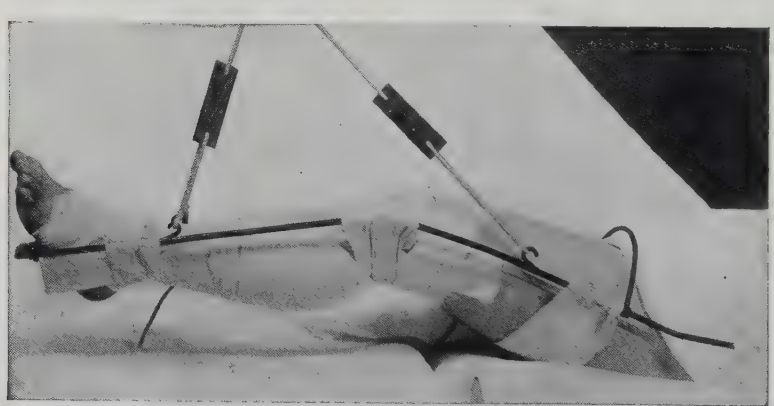

Fig. 944.—Hodgen splint. The pulley suspension cords and splint are arranged and let down on the limb. The extension cord is tied to the end of the splint. Three or four suspending slings are placed under the leg and thigh. The limb is then elevated and extended. Adjustments are quickly and easily made by the tent blocks (Nifong).

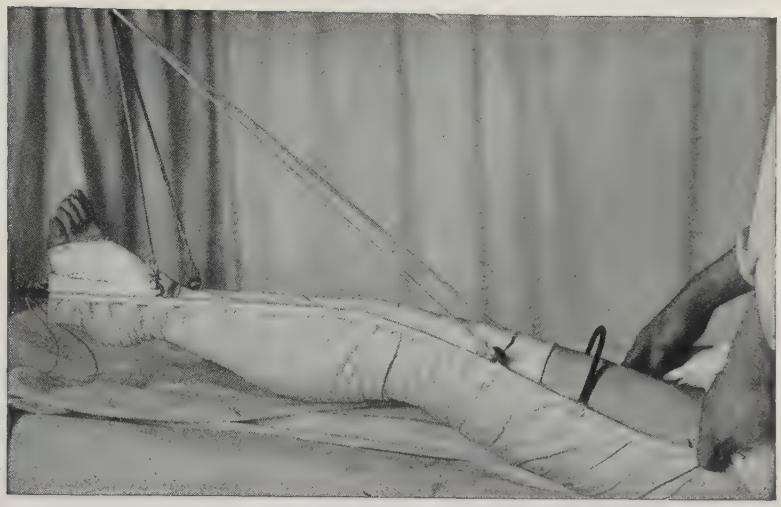

Fig. 945.—Hodgen splint. The suspending slings are applied from the heel to the hip. The interna splint bar reaches to the os pubis. The external splint bar reaches to the trochanter. The top of the limb should be about level with the splint. The thigh portion in this illustration is slung hardly low enough (Nifong).

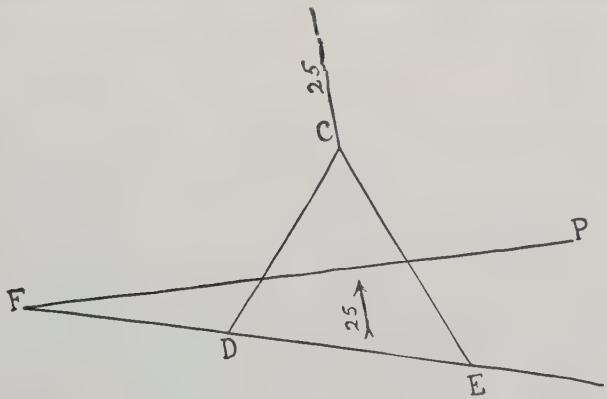

Fig. 946.—Schematic drawing of Hodgen splint in vertical suspension: *F–P*, The limb; *F*, foot; *P*, pelvis; *F–E*, the splint; *C*, suspending cord, suspending vertically; *C–D* and *C–E*, cord suspending splint. The vertical lift is represented as being 25 pounds distributed evenly along the limb. This is the suspending force. There is no extension in this instance illustrated. (After Nifong.)

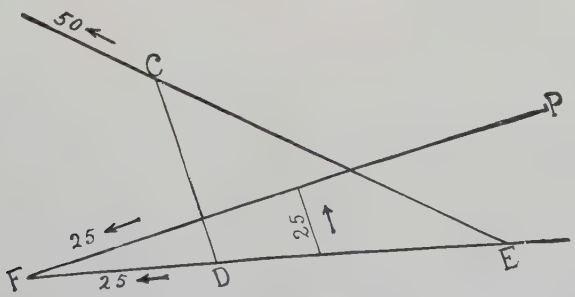

Fig. 947.—Schematic drawing of Hodgen splint in suspension and extension; *F–P*, The limb; *F*, the foot; *P*, pelvis; *F–E*, the splint; *C*, the suspending and extending cord; *C–D* and *C–E*, cords suspending the splint. A pull of 50 pounds at *C* is divided into the original suspending force of 25 pounds at *C* and an extension force of 25 pounds at *F*; *F–P* represents the resultant force. (After Nifong.)

Fig. 948.—Shows Hodgen splint applied with a spring scale measuring a weight of the limb of 25 pounds Vertical suspension above is obtained here (after Nifong).

Fig. 949.—Shows Hodgen splint applied with the proper inclination for securing extension or traction in the limb. The scale shows a pull of 50 pounds, making a suspending pull of 25 pounds and an extending pull of 25 pounds. The limb has applied to it extension adhesive strips similar to those used in the old Buck extension; the extension strips are attached to the end of the splint (after Nifong).

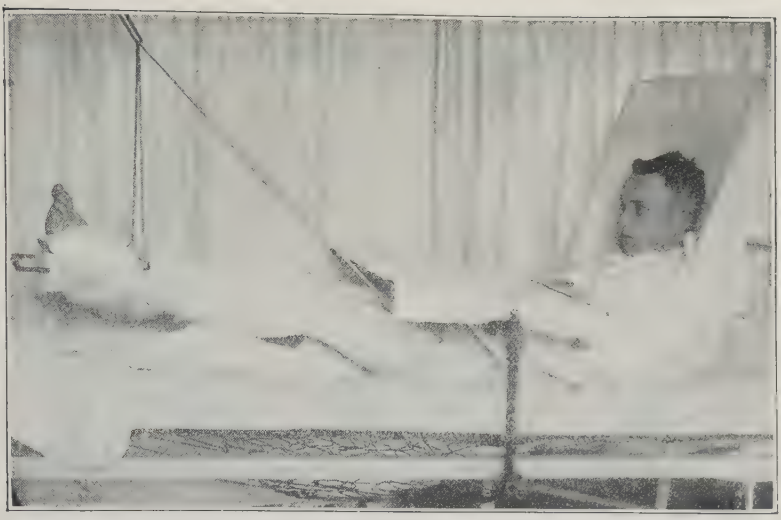

Fig. 950.—This illustrates a comfortable employment of the Hodgen splint. Note the suspension of the limbs, held by the splint, above the bed. Note traction being made by the oblique pull overhead. Note patient slightly elevated in bed. The countertraction here is the weight of the patient's body. The foot of the bed might be elevated and thus prevent the inevitable pulling of the patient down in the bed (after Nifong).

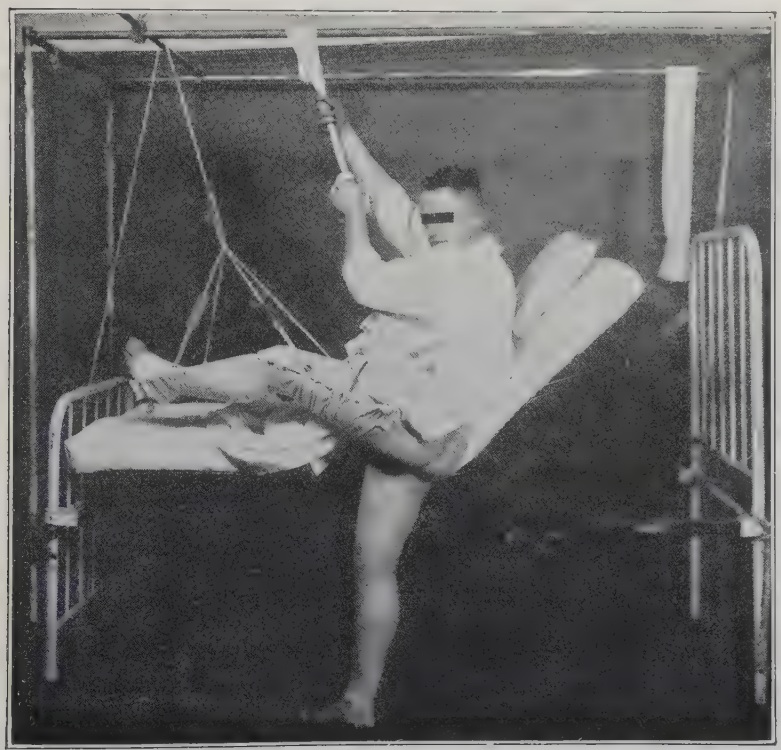

Fig. 951.—Illustrates the possible moving of the patient with the Hodgen splint applied.

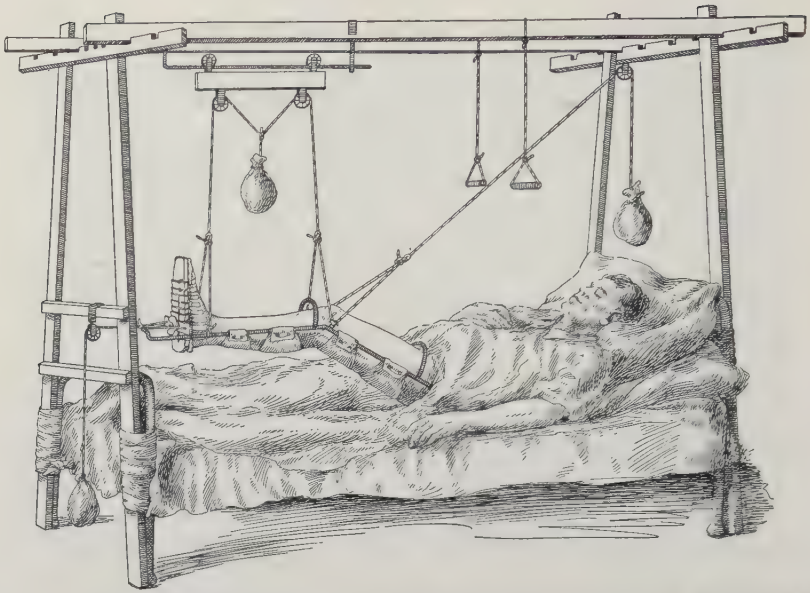

Fig. 952.—A method of treating fractures of the leg using the Hodgen splint and the Sinclair foot board. The Hodgen splint permits motion of the knee and thigh and is at times more useful than the Thomas splint when transportation does not have to be considered. In order to illustrate the foot board the foot has been drawn in a position of eversion, which, of course, is incorrect (Blake).

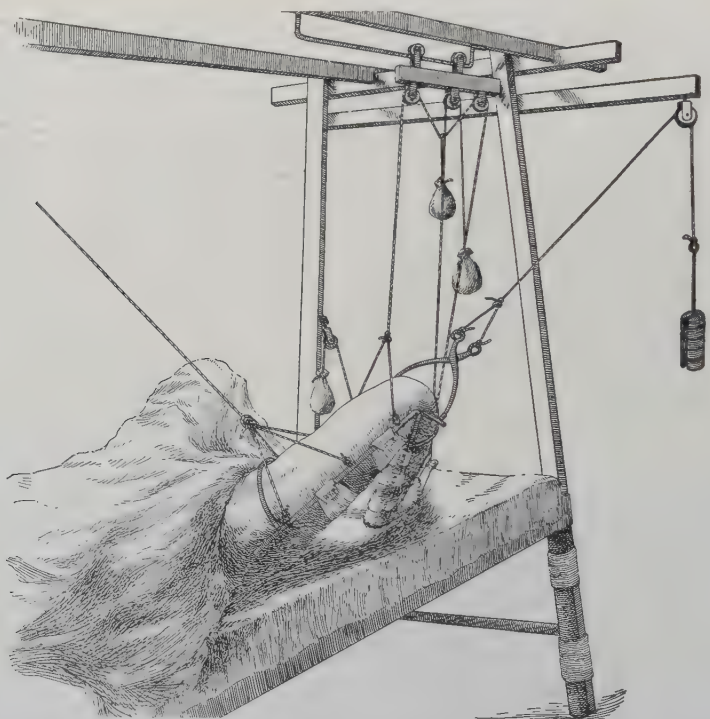

Fig. 953.—Illustrating the method of obtaining abduction and outward rotation in treating high fractures of the femur with the Ransohoff tongs. In this case a Hodgen splint is used, although a bent Thomas splint is preferable if the wounds do not prevent its use. Note the direction of the traction, also the cord and weight attached to the lower end of the splint, which pulls the foot inward, thus rotating the lower fragment outward (Blake).

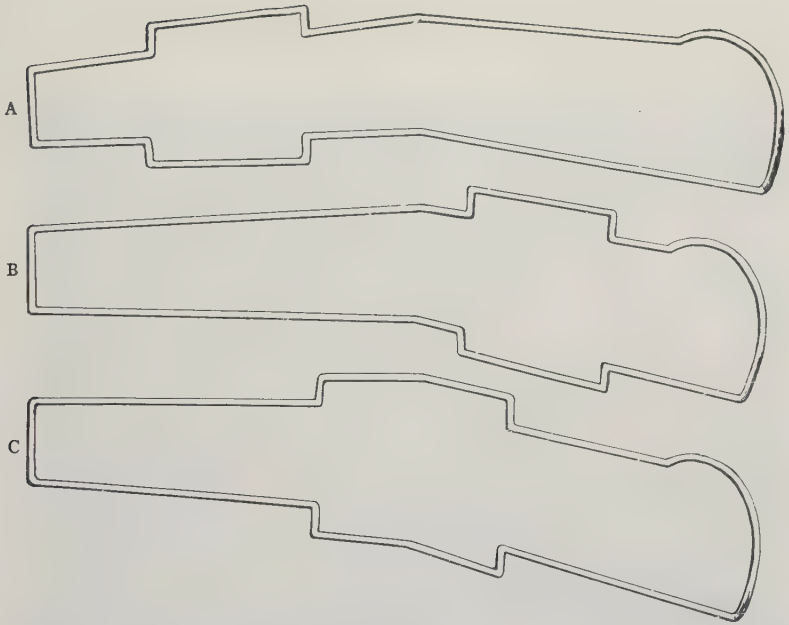

Fig 954.—Models of Hodgen splint spread at leg portion, A; at thigh portion, B, and at knee, C, to give ample room for dressing wounds at these situations (after Nifong).

Fig. 955.—Showing the use of the fluoroscope, looking down through the leg (after Nifong).

Careful refreshing of the bony surfaces and firm apposition of these surfaces are the prime essentials, the fundamental principles, upon which any operative procedure is to be based.

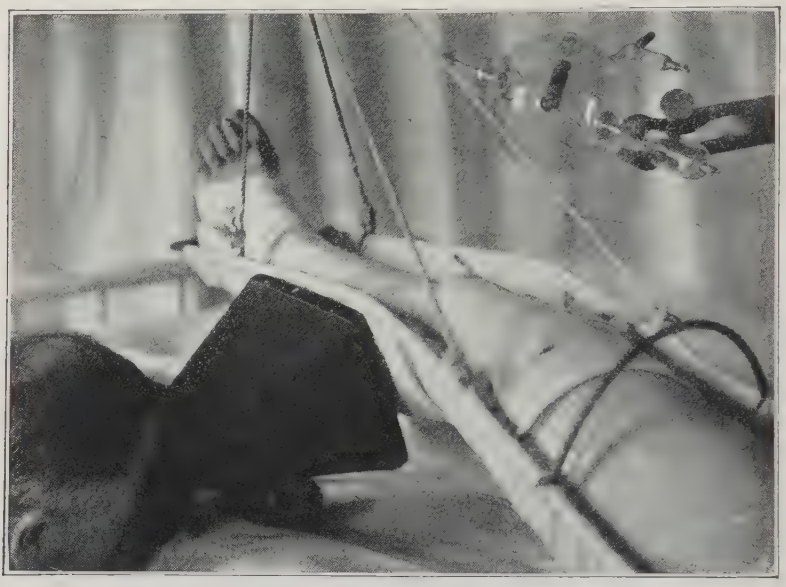

Fig. 956.—Illustrates the use of the fluoroscope, looking transversely. The suspension of the leg renders fluoroscopy relatively easy (after Nifong).

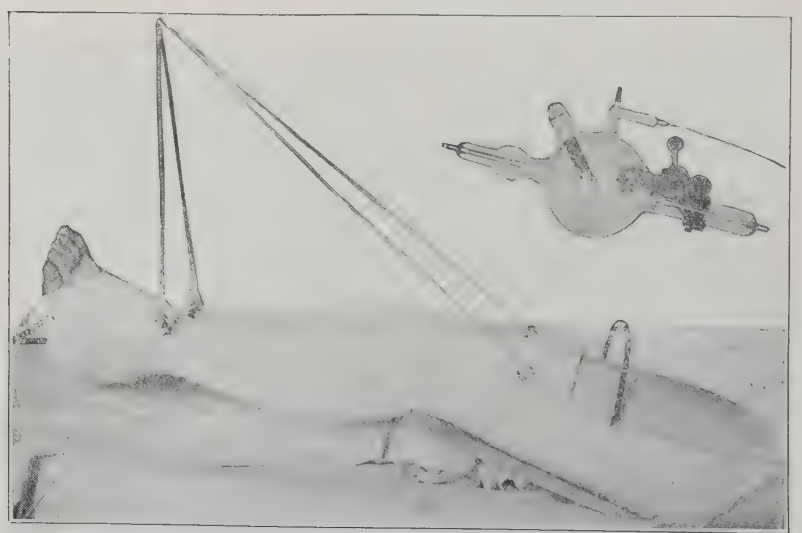

Fig. 957.—Shows *x*-ray tube and plate in position. *x*-Ray examinations are easily made (after Nifong).

Separation of the Epiphysis of the Great Trochanter of the Femur.—This may occur under eighteen years. It follows a fall with violent muscle contraction.

There is local tenderness and a hitch or limp in the gait. It is best treated by placing the patient on the back in bed and keeping the knees apart in extreme abduction for from three to four weeks, until union of the separated epiphysis has begun and all local tenderness has disappeared. If this injury is unrecognized, increasing disability may result and there may be prolonged local signs of discomfort.

FRACTURE OF THE SHAFT OF THE FEMUR

Groups.—Fractures of the shaft of the femur may be arranged for convenience in three groups:

1. Fractures of the upper third (above and below the lesser trochanter).
2. Fractures of the middle third (the shaft).
3. Fractures of the lower third (supracondylar).

In fractures of the shaft the shortening is ordinarily caused by the action of the muscles attached to the pelvis above and to the femur and the tibia and fibula below.

Angular deviations following fracture are usually due to the action of those muscles having their origin or attachments to the femur itself.

1. In *fractures in the upper third* of the shaft the line of fracture is typically forward and outward and when (*a*) above the lesser trochanter, the displacement is caused by the abduction and outward rotation of the upper fragment due to the resultant action of the pectineus and the glutei group of muscles. The hamstrings and rectus muscles draw the lower fragment upward and the adductor muscles draw it inward.

In fractures in the upper third and when (*b*) below the lesser trochanter, displacement is caused by the abduction, outward rotation, and flexion of the upper fragment. The anterior pull forward will be greater than in fractures above the lesser trochanter, due to the attachment of the psoas and iliacus muscles. The lower fragment is drawn upward and inward by the muscles acting in group *a*.

When the line of fracture is oblique (*c*) from above downward and inward (Pearson), the adductor brevis pulls the upper fragment inward and, of course, it is pulled forward as well. This latter fracture is unusual. Obviously *ad*duction of the upper fragment should be treated differently than is the great *ab*duction of this fragment.

A relatively intact periosteum may hinder great overlapping of fragments. If the periosteal stripping from either fragment is considerable there may result great shortening in addition to the usual angular deformity.

2. *Fractures of the Middle Third.*—These fractures have a variable displacement and it does not follow any regularity. The acting force often determines the resulting displacement rather than muscle pull. These fractures will be oblique, comminuted, or transverse. The transverse type is common in the middle of the shaft. There will be angulation, overriding, and lateral displacement (see Figs. 960–965).

The tendency is for gravity to cause a slumping or bending of the fragments backward with the concavity forward.

The maintenance of the normal anterior curve of the femur (see Figs. 810, 820) and the correction of the abnormal outward bowing at the seat of the fracture are to be especially regarded in the program of treatment of fractures at the middle of the shaft.

3. *Fracture of the Lower Third* (*Supracondylar*).—The line of the fracture may be transverse or oblique from behind downward and forward. The lower

Fig. 958.—Fracture of the middle of the thigh. Characteristic deformity.

fragment is displaced backward by the gastrocnemii (see Figs. 1007, 1047, 1048), at the same time rotated outward by the contraction of the adductor magnus and the roll of the leg and foot to the outside caused by gravity. The lower end of the upper fragment may have been driven down toward

Fig. 959.—Fracture of the right femur at the middle. Characteristic deformity. Inward rotation of leg below fracture.

the knee (see Fig. 960). One realizes in this type of fracture how heavy and powerful are the muscles and bones of the thigh.

The linea aspera serves as a thickened buttress (see Fig. 1004) or reinforcement at the middle of the posterior surface of the femoral shaft, giving strength to the long shaft of this large bone.

The line of fracture influences the kind of displacement. The fragments may be driven into unusual positions by a severe force and by the shape of the ends of the fragments.

It is often difficult to secure an effective traction hold on the skin where such power is required to counteract the great displacement.

The knee-joint may be involved in this fracture.

The popliteal vessels and nerves may be damaged by the displaced upper end of the lower fragment. Gangrene of the leg may follow damage to these

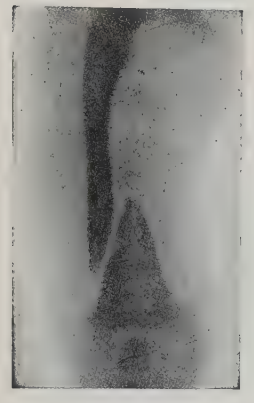

Fig. 960.

Fig. 961.

Fig. 962.

Fig. 963.

Fig. 964.

Fig. 965.

Figs. 960–965.—Fracture of the shaft of the femur. Types of fracture.

vessels. If this deformity is not completely corrected an undue strain may fall on the posterior ligament of the joint and a painful knee result (Pearson).

Symptoms of Fracture of the Shaft.—There is often great swelling at the seat of fracture. The limb lies helpless. Pain, abnormal mobility, deformity, marked rolling of the leg below the seat of the fracture, and crepitus, one or all, may be evident (Figs. 958, 959). The limb is shortened.

Measurement (see Figs. 966, 969, 973) to determine the amount of shortening is to be made from the anterior superior spinous process of the ilium to the internal malleolus of the same side. Great care must be exercised in taking this measurement to see that the patient lies flat upon the back upon a hard and even surface, with the arms at the sides of the body and with no pillow under the head or shoulders. The long axis of the body

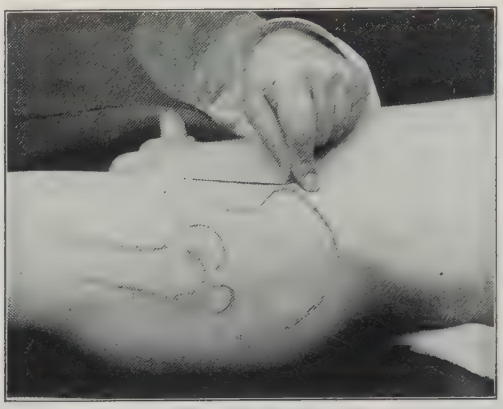

Fig. 966.—Fracture of the thigh. Correct method of measurement from the anterior superior spinous process of the ilium. Position of thumb and finger holding tape.

should be in the same line with the long axis between the legs as they lie with the malleoli approximated, *i. e.*, the chin, episternal notch, umbilicus, the symphysis pubis, the midpoint between the knees, and the midpoint between the internal malleoli should all be in one straight line (Fig. 973, *A–B*). The line joining the anterior superior spinous processes of the ilia (*C–D*) should be at right angles to the long axis of the body and thighs.

Fig. 967.—Measurement of lower extremity. Position of thumbs shown. Note position of limb.

Any variations from this normal position are attended by errors in measurement, which are important. If for any reason the injured thigh cannot be brought easily alongside its fellow, the two limbs should be placed as nearly symmetrical with reference to the median line as possible.

A method of measuring the lengths of the lower extremities differing from the above uses the malleolus as the fixed point, and measures to a line drawn at the anterior superior spinous processes of the ilium. The

finger and tape are not allowed to touch the skin-mark, and so do not displace it.

The Emergency Treatment of Fracture of the Shaft of the Femur.—The war has emphasized the importance of adequate temporary splinting; little disturbance of the fracture at all stages of treatment; careful treatment of shock, and if the fracture is compound, an immediate antiseptic occlusive dressing and early operation (Pearson).

The ideal emergency transport splint is that of Thomas. (See and study Figs. 970 and 971, illustrating its use as applied to a stretcher.) Note also

Fig. 968.—Measurement of lower extremity. Patient lying on the back looked at from above. Position of tape, hands, and limbs to be noted.

Fig. 969.—Note that normally a line from the anterior superior spinous process of the ilium through the center of the patella touches the inner side of the inner malleolus.

the traction hitches for securing a good grip on the foot and angle in transporting a patient in an emergency (see Fig. 972).

The use of the Hodgen splint as an emergency splint is well illustrated in Figs. 976, 977. In the use of the Thomas splint or the Hodgen splint for transport and in emergencies it is important (1) to securely fasten the foot and the bottom of the splint; (2) to snugly adjust the ring or posterior Hodgen strap to the tuber ischii; (3) to support the limb comfortably by slings; (4) to support the foot from dropping forward in plantar flexion; (5) to elevate the lower end of the splint; (6) to hold the splint securely to the side of the stretcher to prevent lateral motion. In Figs. 970, 971 is seen a splint properly applied in which the six essentials have been carried out.

The Transporation of a Patient.—I retain the description of the emergency side splint dressing because the Thomas splint is not yet available to all doctors. The emergency method of putting up a fracture of the thigh or hip is of very great practical importance (Fig. 974). Limbs are frac-

Fig. 970.—End view of Fig. 971.

tured frequently some distance from the proper place for the application of the permanent dressing. It is necessary to transport such cases with the greatest degree of safety and comfort. In order to accomplish this the knee- and hip-joints should be extended, the leg being held straightened

Fig. 971.—Splinting of fractures of the femur for transport from the field. The clothing and boot are not removed. One of the hitches shown in Fig. 972 is placed over the boot; the splint, Thomas or half-ring Thomas, the latter shown applied and snugly adjusted against the tuber ischii. The Spanish windlass is then twisted, drawing the leg well down, when it can be moved without pain; the supporting slings are then knotted; the wire foot support and splint rests are then attached to the splint and the foot tied to the former in order to prevent rotation; the stretcher bar is then attached to the stretcher and the splints tied to it as shown so as to prevent lateral as well as vertical motion. In transportation with the Thomas splint it is absolutely essential to have the splint elevated by the stretcher bar or splint rest (Blake).

in the long axis of the body. The limb should be placed upon a heavily padded board, the width of the thigh, extending from the middle of the calf to above the sacrum. The side splints of wood should be used—one on the outer side extending from the side of the foot to the axilla, the other upon the inner side extending from the side of the foot to a few inches below

the perineum. Upon the front of the thigh is placed a coaptation splint extending from the groin to the patella. All of these splints are carefully padded, preferably with folded sheets or pillow-cases or towels; of course, in emergency work small pillows or coats or shawls may be utilized. It is

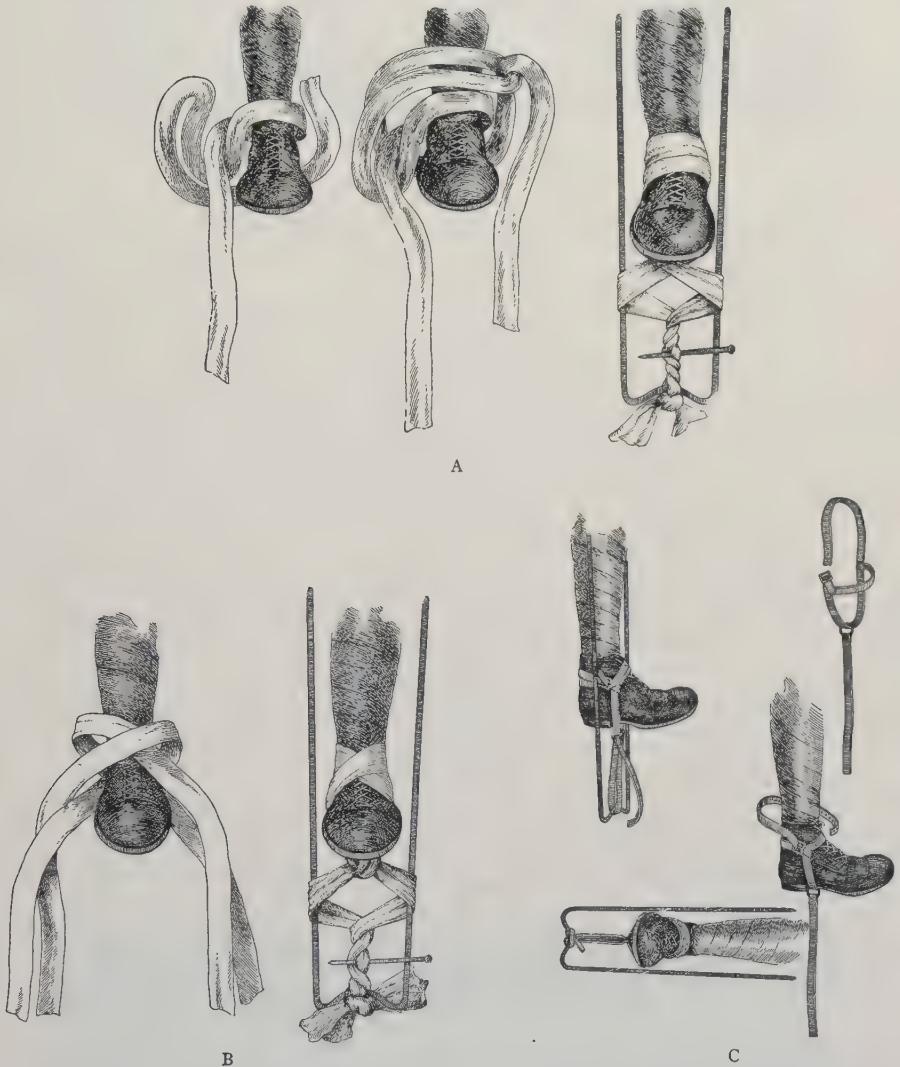

Fig. 972.—Traction hitches for field transportation: A, Collins' hitch; B, Pouliquen hitch; C, adjustable traction strap and saddle girth hitch (Blake).

important that the padding be evenly and intelligently arranged. It will be necessary to place a wide pad between the upper end of the long outside splint, to prevent it from pressing upon the ribs and side of the chest and causing great discomfort. These splints are held in position about the leg, while gentle traction is being made upon the limb, by straps or pieces

of bandage placed above the ankle, below the knee, above the knee, at the middle of the thigh, and at the level of the perineum. The upper end of the long outside splint is held to the side by a swathe about the body and

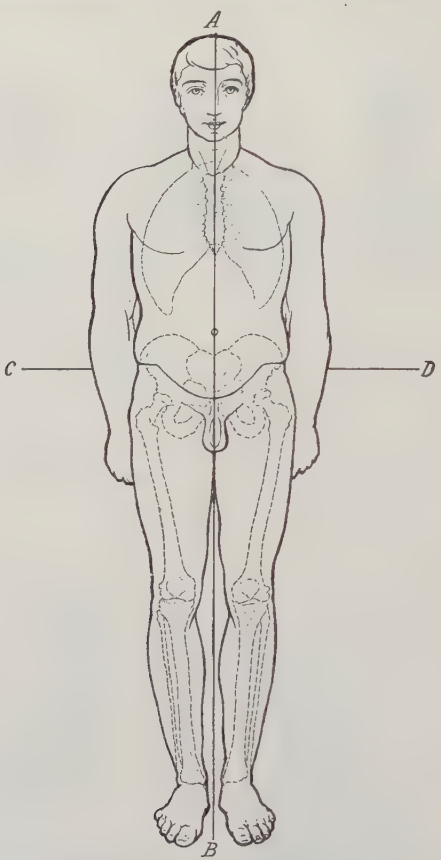

Fig. 973.—Measurement of the length of the lower extremity. Patient represented lying on back, looked at from above. The line joining the anterior superior spinous processes of ilia (*C–D*) should be at right angles to the long axis of the body (*A–B*). In this position only can comparable measurements be made. (Drawn by C. Rimmer.)

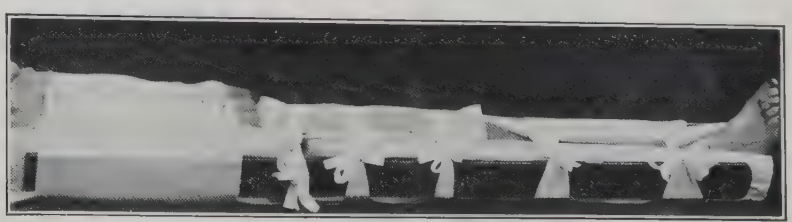

Fig. 974.—Fracture of hip or thigh. Emergency apparatus.

splint. The patient should then be carefully placed upon a stretcher (a Bradford frame is an ideal form of stretcher) improvised for the purpose. With this apparatus snugly applied the patient may be securely and comfortably transported.

Fig. 975.—Fracture of the thigh. Method of holding leg in order to detect fracture of the thigh. Pelvis is steadied by an assistant.

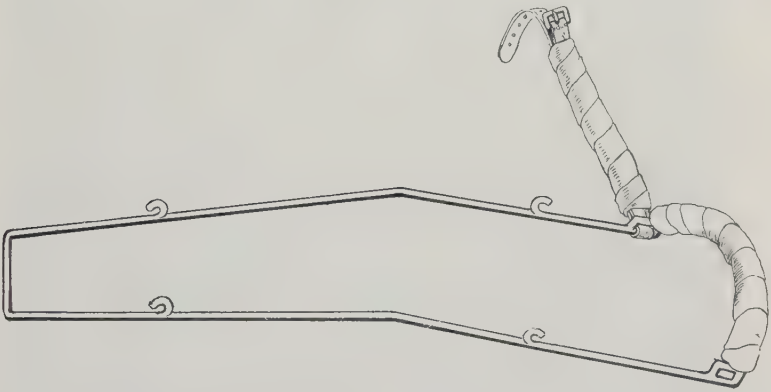

Fig. 976.—The Hodgen transport splint open ready for application. The free strap is to be applied to the posterior surface of the thigh to prevent splint from shifting (Nifong).

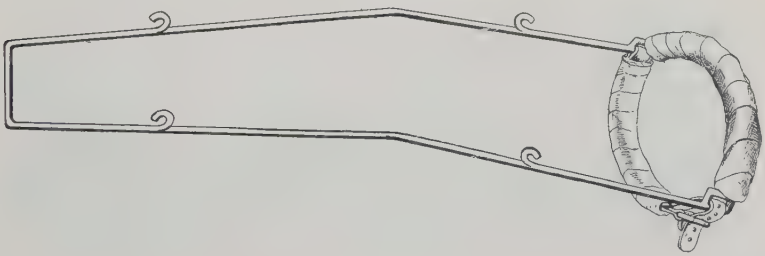

Fig. 976A.—Hodgen splint. Note method of strapping transport splint to the thigh (Nifong).

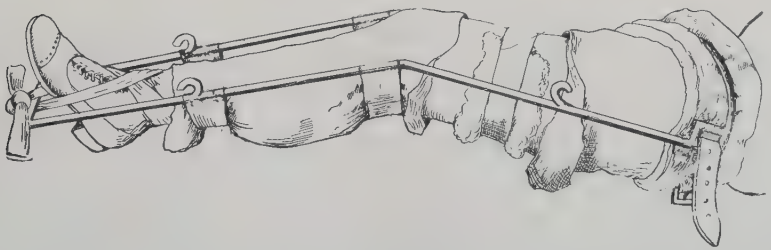

Fig. 977.—Hodgen splint applied in emergency. Note first-aid dressing to outer side of thigh; foot slung to cross-piece with temporary extension. The leg and thigh are suspended in the splint (after Nifong).

Principles Underlying the Treatment of Fractures of the Shaft of the Femur.—The four chief principles underlying the treatment of fractures of the femoral shaft are the need for extension and counterextension upon the bony fragments, the suspension of the fractured limb, and the early movement of the contiguous joints through active guarded motion.

The hip-joint is a ball-and-socket joint. The movements at the hip are very free in all directions, and therefore it is a fact that no force can be transmitted through the hip-joint to the point of fracture until the hip-joint motions reach their limit in any particular direction. These limits

Fig. 978.—Same case as in Fig. 979. Suspension so arranged that voluntary flexion at knees is practicable (Leland).

of movement are very wide, so wide, in fact, that practically the hip need not be immobilized when treating fracture of the femoral shaft.

In the above anatomico-physiological fact rests the employment of suspension extension apparatus in the treatment of fracture of the shaft of the femur.

The *great fascia of the thigh* (the fascia lata and its iliotibial band (see Fig. 821) and the broad sheets of the intermuscular septa, the attachment of these fasciæ to the bone through the linea aspera): all these fascial planes of tissue (see Fig. 1004) serve not only to contain the large and long muscles of the thigh, but—and this is important—they serve to direct the pull of

the muscles and to determine somewhat the deformity following fracture of the femur.

The fascia lata itself is attached above to the pelvis. It has attached to it the tensor fasciæ femoris and a portion of the insertion of the gluteus maximus muscles.

The fascia lata is attached below to the border of the patella and is continuous with the fascia of the leg.

Following a fracture this great expanse of fascia is relaxed. When this fascial mass is stretched to its normal length again it tends to reduce the

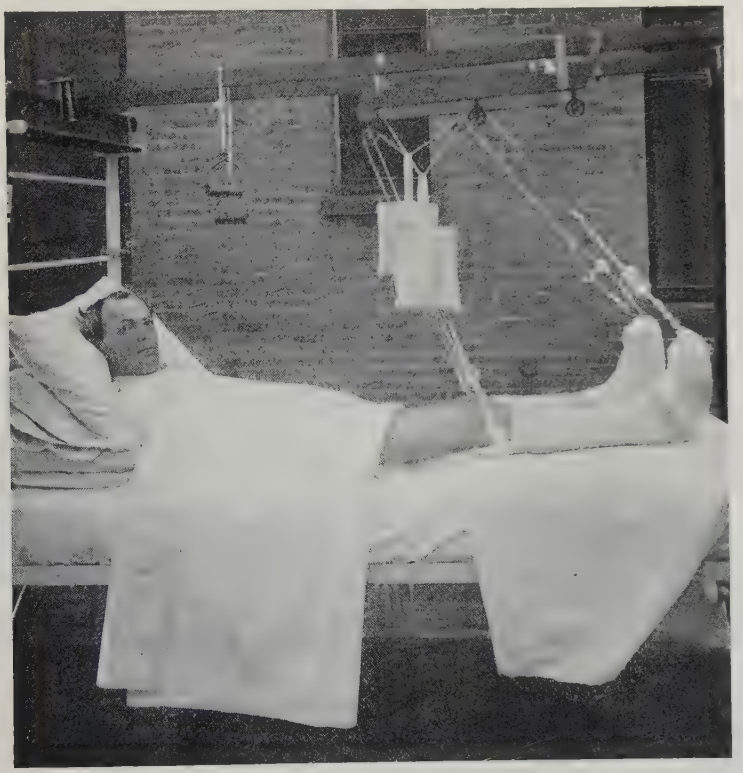

Fig. 979.—Same case as in Fig. 978. Suspension of both legs in Cabot posterior wire splints during convalescent period (Leland).

fragments and keep the bone in its natural position. I believe that the relaxation, retraction, of these fascial planes is responsible in large measure for the difficulty attending reduction of fractures of the femur. Moreover, it is a fact that delay in setting the fractured bone is attended by increasing difficulties of reduction largely because the fasciæ become stiff, filled with round-cell infiltration. As time elapses these planes of fasciæ can with greater and greater difficulty be stretched to their normal lengths.

The proximal fragment, if uninfluenced by exterior forces, always occupies a position in which the muscles attached to it are at rest.

If the distal fragment is brought into line with the proximal when it occupies the position of physiological rest and sufficient traction is made in the same line to overcome shortening, the restraining effect of the stretched soft tissues is sufficient to provide the slight extrinsic force necessary to preserve the relative position of the fragments, even if considerable motion takes place at the adjacent joints (Blake).

There are two connective-tissue septa or broad bands lying between muscle bundles connecting the femoral shaft with the superficial enveloping fascia lata. The first septum, extends from one lip of the linea aspera to between the adductor magnus and the vastus internus. The second, the lateral intermuscular septum extends from the linea aspera between the short head of the biceps and vastus externus. The extensor group of muscles is thus separated from the flexor and adductor groups.

In the fact of the necessity for stretching both muscle *and* fascia lies the reason for the use of extension and counterextension in the treatment of fractures of the shaft of the femur.

The Suspension of the Fractured Limb.—The suspending of a fractured limb, whether it is the upper or lower extremity, is comfortable for the patient, nursing the patient is easier, there is less pain and discomfort in dressing compound fractures, there is less swelling of the limb, the primary swelling disappears rapidly, there is less stiffness of joints after fracture, the repair of the fracture seems to be rapid, excessive callus is less frequently seen, non-union is thought to occur less frequently, there is a better circulation in the whole limb, there is greater immobilization of the fracture along with an increased mobilization of joints.

Consequently, when it is possible, a fractured limb should be suspended. The use of the Thomas splint and the Hodgen splint (see Figs. 943–945) and splints of their type allow readily of suspension. See various illustrations of suspended fractures.

The suspension of fractures combined with efficient bony traction will, if carefully supervised and completely carried out, reduce very materially the number of primary operations upon simple fractures.

With the suspension of a fracture function never ceases, therefore it is estimated that a saving of nearly 50 per cent. may be made in the period of incapacity.

The relaxation secured by posture in flexion is remarkable. The moving of joints actively contiguous to the fracture prevents muscle atrophy and painful and disabling adhesions in the various fascial planes and in the neighboring joints. Pain is greatly diminished by active movements.

Buck's Extension, Materials for, and Application of.—Adhesive plaster may be used in applying traction. It is convenient of application and sometimes serviceable, especially in children. In adults it is apt to slip and excoriate the skin. Such excoriation might delay a necessary operative procedure. Consequently, if there is any likelihood of being obliged to operate in a given fracture of the femur and heavy traction is required, Sinclair glue or skeletal traction had better be used, and thus not only will the sur-

geon be enabled to secure primarily a more effective trial traction, but he will avoid the disheartening delay caused by an inefficient adhesive plaster skin traction.

Buck's extension is an effective retentive apparatus in a few simple not greatly displaced fractures.

Traction in the long axis of the leg may not correct all lateral displacement. Traction applied at right angles to the long axis of the leg over the side of the bed will assist materially in reducing certain lateral displacements (see Fig. 980).

The method described for the application of plaster skin traction is universally applicable in principle to any plaster skin traction, whether for the upper or lower extremity.

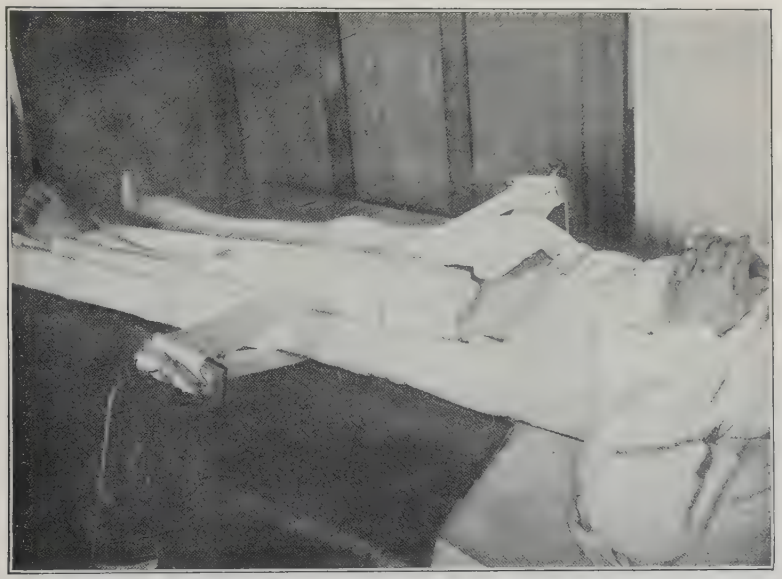

Fig. 980.—Fracture of the shaft of the femur. The fragments cannot be brought into exact apposition by simple longitudinal traction, consequently note lateral traction being made both externally and internally by broad straps and weight and pulley. The two side splints, coaptation splints, traction being made in long axis of limb, swathe about long outside splint and body, are all seen in the figure.

Traction and immobilization may be maintained by a modified Buck's extension apparatus. *Materials needed for a modified Buck's extension for the lower extremity:* Two strips of *adhesive plaster*, each 2 inches wide and long enough to extend from the seat of fracture to the internal malleolus. Surgeon's adhesive plaster is non-irritating to the skin, and is prepared in rolls of convenient width. To each strip of plaster at the ankle end should be stitched a piece of webbing the width of the plaster and about 6 inches long. Prepare five other strips of adhesive plaster, all of which should be $1\frac{1}{2}$ inches wide. Three of these strips should be long enough to encircle respectively the leg above the malleoli, the knee above the condyles, and the thigh an inch below the seat of the fracture. The remaining two strips of plaster should be long

enough to extend spirally from the malleoli around the leg and thigh to the seat of fracture. Prepare also a *roller bandage* of gauze or cotton cloth, a curved or straight *ham-splint* properly padded, and three adhesive straps for holding the ham-splint.

In addition, three *coaptation splints* for surrounding the thigh are

Fig. 981.—Pulley arranged on broom handle to be fastened at foot of bed for carrying extension cord.

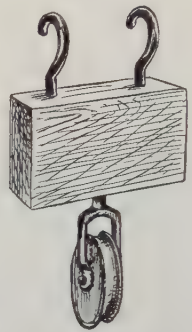

Fig. 982.—Pulley arranged for bed.

required, also six webbing *straps* with buckles or strips of bandage to be used as straps; fresh *sheets* or pillow-cases or towels for padding; a *swathe*, to encircle the pelvis, made of unbleached cotton cloth or medium weight Shaker flannel; and a long outside *splint of wood*, 4 inches wide, to extend from the axilla to 6 inches below the sole of the foot. To this last a cross-piece, 18 inches long, should be fastened, making thus a long T-splint. The list is completed by two *towels* for perineal straps, *safety-pins*, a *pulley*, which can be bought at little cost at any hardware store

Fig. 983.—Spreader of wood for preventing extension straps from chafing ankle and foot. Cord for attaching weight.

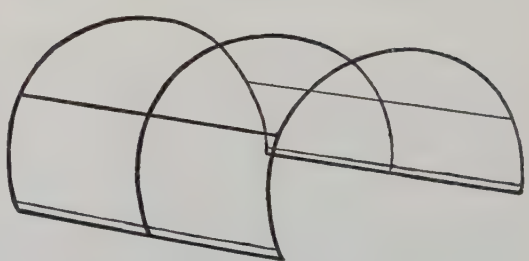

Fig. 984.—Bed-cradle. Can be made of barrel hoops.

(see Fig. 981). This pulley should be screwed into a *broom handle* cut to the right height. A block with hooks above and a pulley below will some-

times be found to be more convenient than the broom-handle arrangement (Fig. 982). A *spreader* (Fig. 983), which is a piece of wood 2 inches wide and a little longer than the width of the foot, perforated at its center for the extension weight cord. There should be provided a *cord*, 3 feet long, size of a clothes-line; *two bricks* or wooden blocks for elevating the foot of the bed; four *sand-bags*, 20 inches long and 6 inches wide; a *cradle* (Fig. 984) to

Fig. 985.—Boy eight years of age. Supracondyloid fracture of the femur. Note splintering of fragments. Displacement of fragments. Epiphyses of lower end of femur and upper ends of tibia and fibula. Note patella. Impaction was broken and the deformity corrected.

keep the weight of the clothes from the thigh—the cradle may be a chair tipped up, or barrel-hoops nailed together.

Application of the Modified Buck's Extension.—All the materials being in readiness and at hand, the patient having been etherized and the fracture examined, the thigh and leg and foot are first washed with warm water and Castile soap and thoroughly dried.

Then the padded posterior coaptation or ham-splint is applied and held by three straps of adhesive plaster, one at each end of the splint and one

below the knee (see Fig. 987). If the curved ham-splint is used, the padding (one sheet of sheet wadding) should be laid upon the splint evenly through-

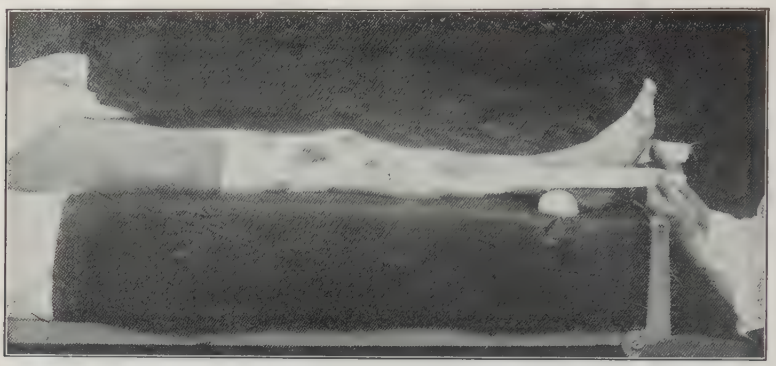

Fig. 986.—Fracture of the thigh. Adhesive-plaster extension strips; long, upright, circular, and obliquely applied strips.

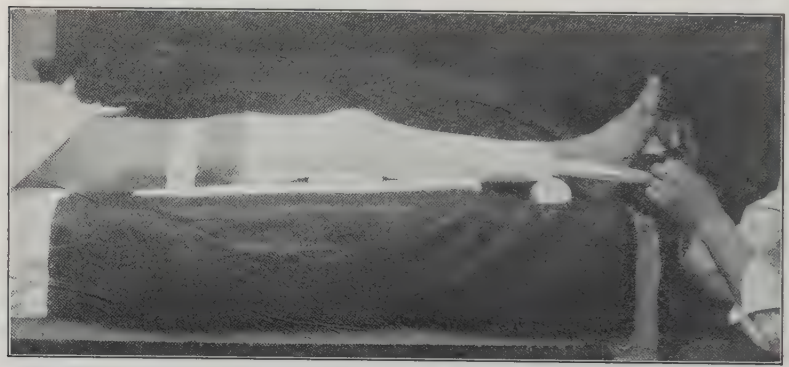

Fig. 987.—Fracture of the thigh. Extension strips applied, covered by bandage. Ham-splint applied; two straps and pad in ham.

Fig. 988.—Fracture of the thigh. Extension strips applied. Cotton bandage. Ham-splint, straps, pad, and coaptation splints about the seat of fracture. Straps and buckles.

out. If a straight ham-splint is used, the padding should be applied evenly, and at the middle of the ham, behind the knee, should be placed an addi-

tional pad (Fig. 988) in order to support the knee in its natural position. This additional pad should be placed between the splint and the layer of sheet wadding. The tendency of the padding of the ham-splint is to slip

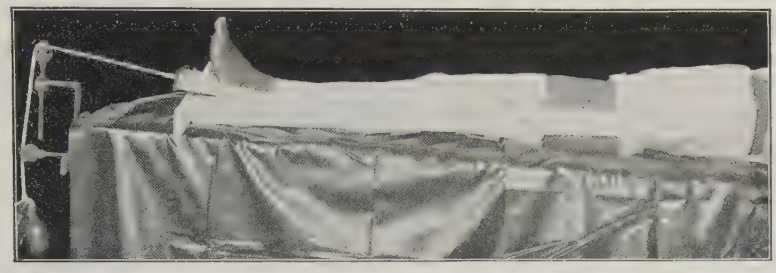

Fig. 989.—Fracture of the thigh. Completed apparatus as in Fig. 988, and, in addition, a long outside T-splint straps, and swathe. Weights applied.

away from each end of the splint and thus leave it unduly pressing into the thigh and calf. It is wise to hold this padding in place by strips of adhesive plaster at each end of the splint. The three thigh coaptation splints

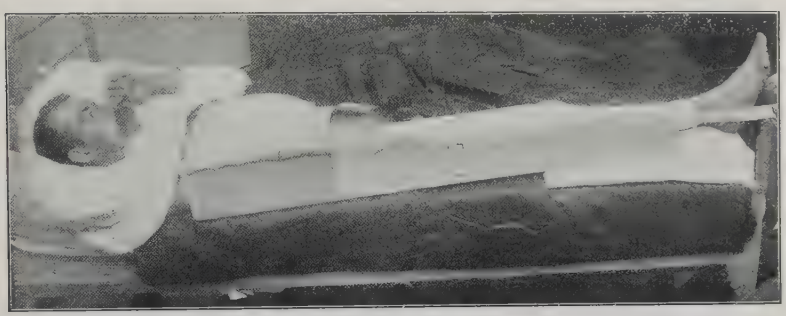

Fig. 990.—Fracture of the thigh. Completed apparatus with bed elevated. The outside splint is broad and without the T foot-piece. The swathe is very snugly applied.

should next be put in position—one anteriorly, extending the whole length of the thigh from groin to patella; one externally, extending from trochanter to external condyle; and one internally, extending from just below the perineum

Fig. 991.—A fracture of the femoral shaft, so placed between two long side splints and anterior and posterior coaptation splints with a swathe about the body that transportation is possible with a minimum of discomfort and danger of damage.

to just above the adductor tubercle (see Fig. 988). The best padding for these splints is a soft dressing towel folded the length of the splints and placed evenly about the thigh. These splints are held by an assistant while three or four

straps are tightened sufficiently to hold them firmly in place. While these coaptation splints are being applied it is very important that steady traction be made upon the lower fragment in order to maintain its position. The straps of the coaptation splints are then finally tightened. The long outside splint with the T cross-piece is then padded with sheets and applied to the side of the limb and the body (Fig. 989). The upper end of the splint is inclosed in a swathe, which passes around the body and is fastened with safety-pins. The thigh and leg are held steadily to the outside splint by two or three straps (Fig. 990). The assistant, making extension, exchanges his traction for that of the weight and pulley. The foot of the bed is raised upon blocks or bricks, in order to provide the counterextension by means of the weight of the body. The heel is protected from undue pressure by a ring. The foot is kept at a right angle with the leg (Fig. 992). The sandbags are laid along the inner and the outer sides of the limb to add greater

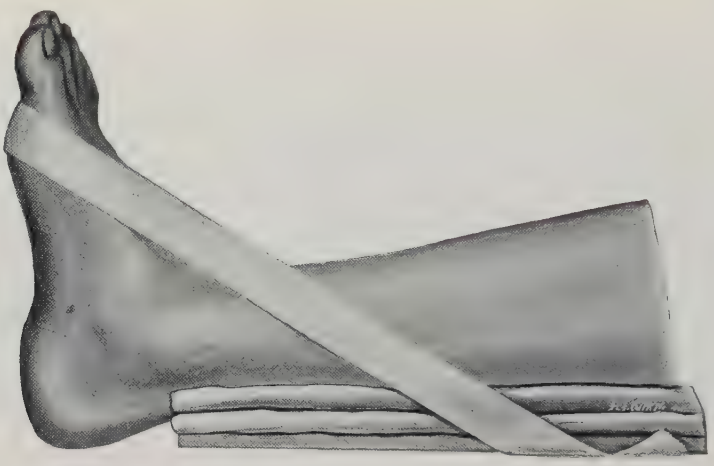

Fig. 992.—Form of stirrup to prevent the foot assuming an equinus position.

steadiness to the apparatus. The cradle is placed over the foot and the leg (see Fig. 984).

Balanced Traction.—The use of a straight bed-resting traction has very largely been replaced by the more effective balanced traction. The limb is put in a position of physiological rest, *i. e.*, for the lower extremity semiflexion of the hip and knee. This method is the underlying one in all forms of traction and is mentioned again under the Thomas splint with the Pearson knee attachment (p. 521). It is mentioned, too, under the method of treating femoral shaft fractures by immediate reduction and plaster-of-Paris splint fixation.

The Use of Sinclair's Glue Extension.—This extension is less irritating to the skin than ordinary adhesive plaster, secures a firmer hold, and thus enables the surgeon to apply a more effective traction force than by the old adhesive plaster method.

The *formula for Sinclair's glue*, to be used in applying traction straps for extension in cases of fracture of the long bones: This description is taken from Major Sinclair's own paper.[1] The glue used must be of the best quality, and a simple test for this is as follows: Place 4 ounces of glue in a basin of 4 pounds of cold water and leave in a cool place for twelve hours. If the glue is dissolved, it is bad; if coherent, gelatinous and weighing 8 ounces, it is good; if it weighs 16 ounces, it is very good; and if 20 ounces, it is the best which can be obtained. The formula is:

Very good glue	50 parts
Water	50 parts
Thymol	1 part
Glycerin	4 parts in summer and 6 parts in winter

Soak for twelve hours, then melt in a water-bath.

Neutralize to litmus with sodium hydrate, as commercial glue at times contains free hydrochloric acid.

The glycerin prevents the glue from drying, becoming brittle, and cracking, while at the same time its deliquescent properties enable sweat to be absorbed and evaporated from the surface. The thymol acts as an antiseptic, and glue prepared in this manner is sterile and should be kept in air-tight 1-pound tins.

Failure in using glue may be due to an inferior type of glue, paying insufficient attention to its preparation, or to allowing it to remain on the limb too long.

In *applying the extension* the following points should be noted:

1. The skin should not be shaved.

2. In order to remove all grease the skin is washed with soap and hot water containing 4 drams of sodium carbonate to the pint. Glue will not adhere to a greasy surface.

5. The skin is dried and glue applied evenly and thinly, all hair of the limb being brushed in an upward direction. The skin should be warm when the glue is applied, otherwise slipping is liable to occur.

4. Two strands of gauze, eight layers thick, are now laid on the limb. Tension is kept on the gauze all the time; it is brought quickly but carefully into contact with the leg on the medial and lateral aspects. The skin overlying the subcutaneous surface of the tibia is avoided both with glue and gauze, for if extension be exerted on it blistering will frequently occur. Finally, a loosely woven roller bandage is applied commencing a handbreadth above the malleoli and ending just below the knee-joint.

The glue extension once in position is not by any means completed. After about ten days the muscles of the leg will be found to have atrophied, and as an extension cannot shrink, it must wrinkle. The pull will then be exerted along lines instead of from the whole surface of the skin, and if continued will cause blistering. The extension should, therefore, be palpated

[1] Transactions of the International Society of Surgery, Paris, July, 1920.

daily, and if any wrinkling is felt or the patient complains of a burning sensation under the extension, it should be changed immediately, the traction in the meantime being maintained by the foot-piece. With glue extension it is usually safe to raise the foot of the bed 8 to 10 inches; should this prove insufficient to bring the limb to its full length in forty-eight hours, mechanical extension should then be employed.

If extension by glue from the skin is not possible because of the presence of wounds or because the patient's skin is hypersensitive and blisters occur from the trauma exerted (this happens in about 15 per cent. of cases of fracture of the femur and very rarely occurs in fractures of other long bones), or because the reduction of the deformity requires an excessive pull, resort must be made to some more direct form of extension.

To be used if Sinclair's glue is unobtainable: The adhesive-plaster Buck extension. The long straight strips of adhesive plaster with the webbing attached or applied to the middle of the two sides of the leg and thigh up to the seat of fracture. The junction of the adhesive plaster and webbing should be brought to just above the malleoli. The two spiral and then the three circular strips should next be applied as indicated (see Fig. 986). Over the extension is placed a roller bandage, snugly and evenly inclosing the foot (see Fig. 987). The bandage steadies the adhesive plaster, prevents swelling of the foot, and affords comfort.

Method of Immediate Reduction According to Campbell's Technic.— A fracture table (Hawley) is absolutely essential, with attachments for countertraction and direct traction.

A Roentgen-ray fluoroscopic equipment is also an essential unless a plate control is available. Frequent *x*-ray controls of the exact position of the fragments is thus assured, thus intelligently guiding reduction and recording position when finally immobilized.

1. The patient is given a general anesthetic to complete muscular relaxation.

2. The uninjured limb is fixed to its foot-piece with slight traction to help steady the pelvis and body.

3. Forced traction in a perfectly straight line is made in order to secure as nearly as possible complete muscle relaxation.

4. The injured thigh is flexed to about 45 degrees and slightly abducted, or such position is assumed as will be most likely to maneuver the lower fragment to meet the upper fragment.

5. The fragments are angulated until by traction and position the ends of the bones are made to impinge and can be locked.

6. The thigh is then gradually straightened until the normal anteroposterior and lateral alignment is secured.

7. If the fragments slip by each other, the maneuver is repeated. The position is checked by the *x*-ray.

8. The position is maintained by such pressure and traction as is necessary.

9. Traction is made on the foot, under the knee, and wherever helpful.

10. A plaster-of-Paris splint is put on, extending from the upper chest, nipple line, to the toes on the affected side and to the knee on the uninjured side. The hip lies flexed to about 40 degrees or more. Thus fixation is assisted through pressure at the buttock and the calf of the leg, an effective double inclined plane.

Orr's Method.—After reduction of the fracture essentially as by the Campbell method while traction is being maintained, there is applied a double spica to the ankle on the injured side, and to below the knee on the well side; a cross-bar is formed below the knees between the two legs of the spica.

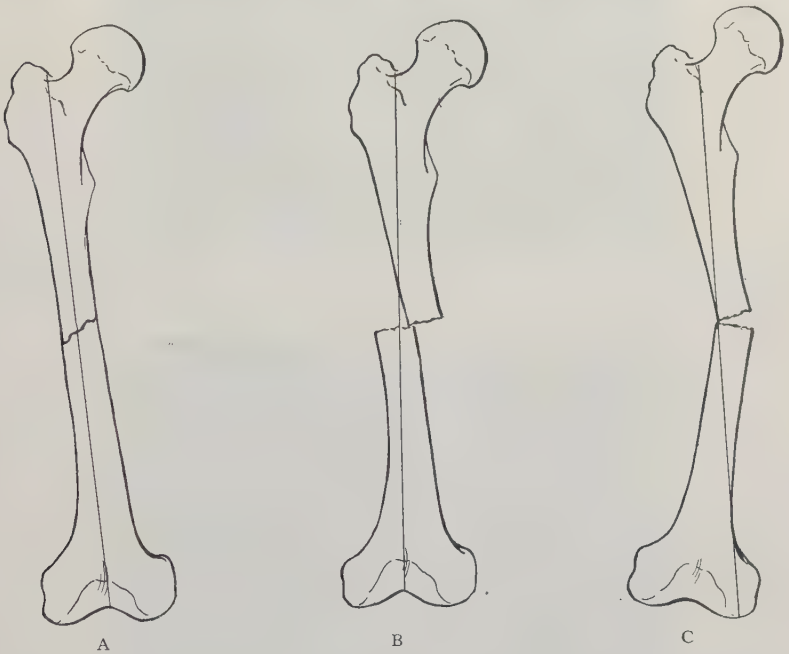

Fig. 993.—Fracture of the shaft of the femur at its middle: A, End-to-end apposition of fracture; perfect alignment. B, Imperfect apposition; good alignment. C, End-to-end apposition; faulty alignment.

When the plaster has set, the traction straps are turned back over the plaster splint at the ankle. An additional plaster is applied so as to anchor the traction straps, thus maintaining moderate traction. The plaster-of-Paris splint includes the foot, a guide as to rotation of the limb, and keeps the foot at a right angle with the leg. The *x*-ray helps to record the position. The patient is placed on a bed with its foot elevated. Twenty or 30 pounds traction should be fastened to the cross-bar between the legs of the double spica. This traction seems to prevent muscle spasm and helps in immobilization.

Remarks on the Immediate Reduction and Fixation in a Plaster-of-Paris Splint.—Repair begins immediately after fracture, consequently the early reduction diminishes the later postfracture swelling.

A plaster-of-Paris splint may be safely put on in most early fractures. The surgeon must be on the alert for early danger signs of too great pressure.

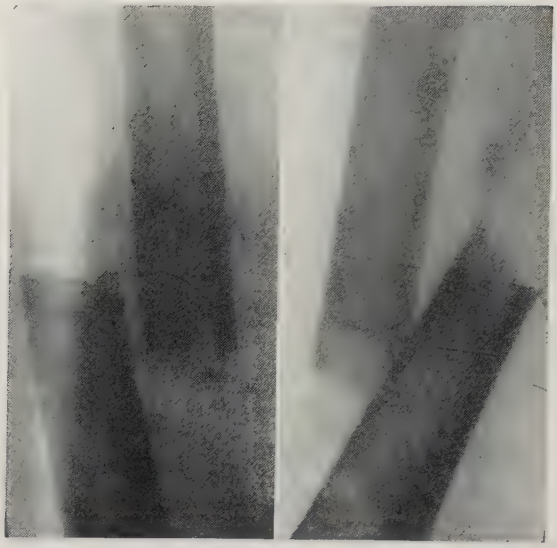

Fig. 994.—Anteroposterior and lateral views of fracture of the middle third of the femur in an adult (Campbell Surg., Gyn., and Obst., November, 1924).

Fig. 995.—Anteroposterior and lateral views of the same patient as in Fig. 994, four weeks later, showing good reduction and early callous formation (Campbell, Surg., Gyn., and Obst., November, 1924).

Adhesive plaster or, better, Sinclair glue traction strips may be applied before or after reduction and permanent traction be maintained while the plaster-of-Paris splint is on, to prevent slumping of the bones.

Fig. 996.—Anteroposterior and lateral views showing a fracture of the lower third of the femur in an adult (Campbell, Surg., Gyn., and Obst., November, 1924).

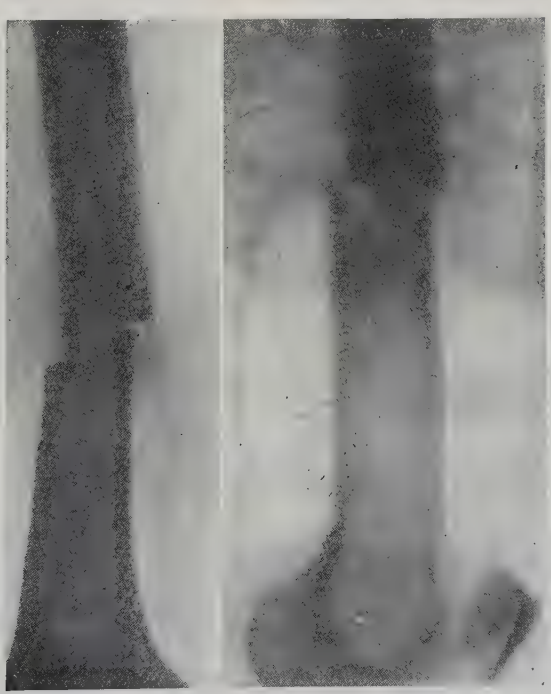

Fig. 997.—Anteroposterior and lateral views of the same patient as in Fig 996, four weeks later, showing good reduction and early callous formation (Campbell, Surg., Gyn., and Obst., November, 1924).

By this method the knee- and ankle-joints are immobilized so long that some stiffness will exist and persist a varying time after the removal of the

splint. About 5 per cent. of Campbell's cases had disabling stiffness of the knee. The stiffness following immobilization of the knee will be less persistent in childhood than in adult life.

The plaster splint is always to be removed at the end of two (childhood) or three (adult) weeks, the alignment of the limbs checked up by *x*-ray, and the joints gently moved. Any slight change can be easily made at this time while the callus is soft. A second plaster-of-Paris spica splint is applied, not including the other hip if there is beginning union and a satisfactory position.

Many oblique and transverse fractures can be held by this method.

Fig. 998.—Anteroposterior view of a fracture of the shaft of the femur in an adult. Note deformity and shortening (Campbell, Surg., Gyn., and Obst., November, 1924).

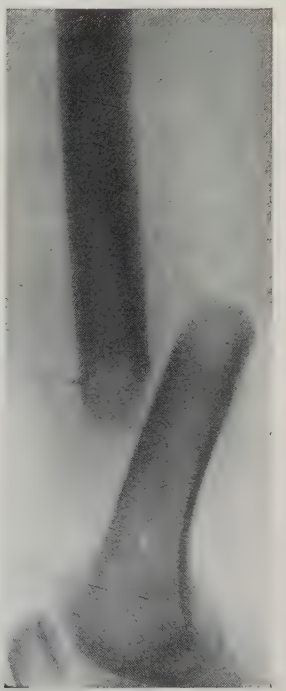

Fig. 999.—Lateral view of same femur as shown in Fig. 998. Note deformity and shortening (Campbell, Surg., Gyn., and Obst., November, 1924).

The most difficult fracture to hold by this method is the short, smooth, slanting break, hard to lock and liable to slip during the first week. In such cases general alignment can be maintained without anatomical reposition or direct fixation by operation may be applied.

It is possible to secure reposition of fragments as long as three weeks after the accident. Much depends on the callous output and its rapidity of calcification.

The muscular development of the individual and the degree of the retraction of the fascia are to be considered in every case.

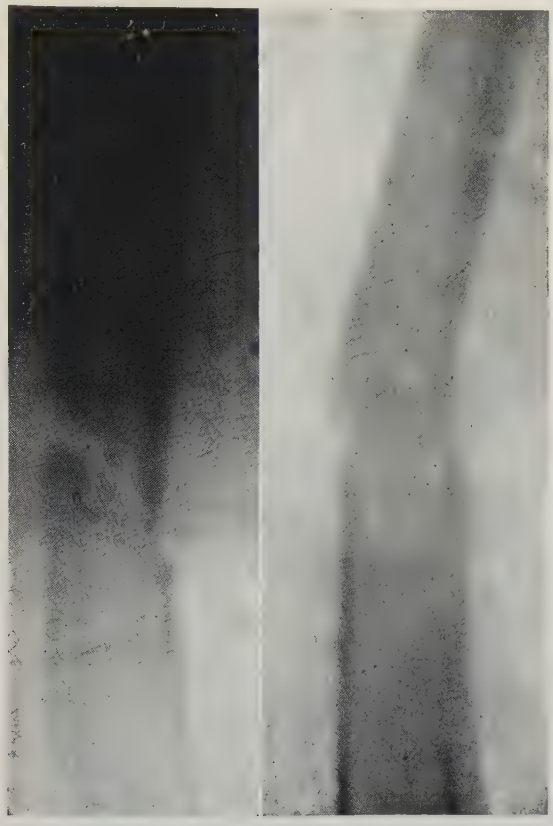

Fig. 1000.—Anteroposterior and lateral views of the same patient as in Figs. 998 and 999 in cast of plaster of Paris two weeks after reduction; end-to-end apposition fragments are locked, alignment is good (Campbell Surg., Gyn., and Obst., November, 1924).

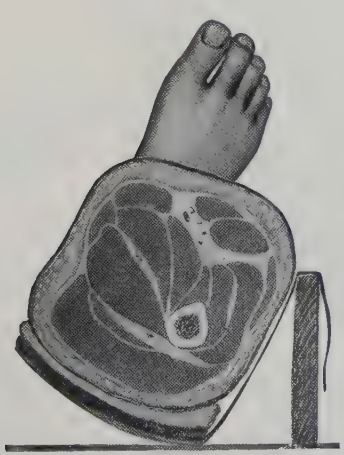

Fig. 1001.

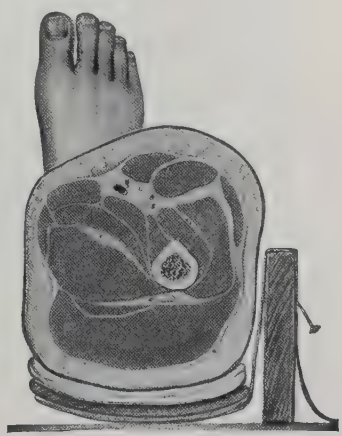

Fig. 1002.

Figs. 1001, 1002.—Diagram of section of leg and splint to show how a strap carried from the back of the leg over the long side-splint can prevent eversion of the foot and leg. (Compare with Fig. 989.)

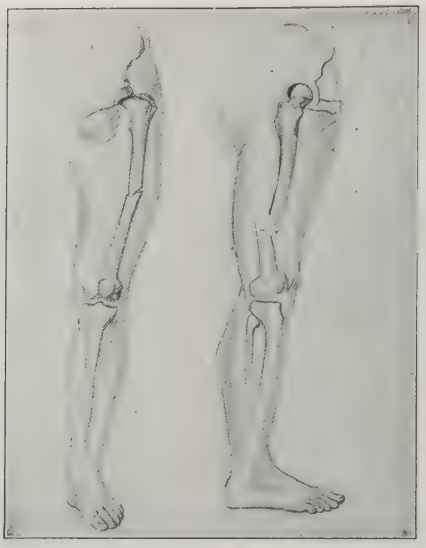

Fig. 1003.—The more usual deformities in fracture of the shaft of the femur. Outward and posterior bowing

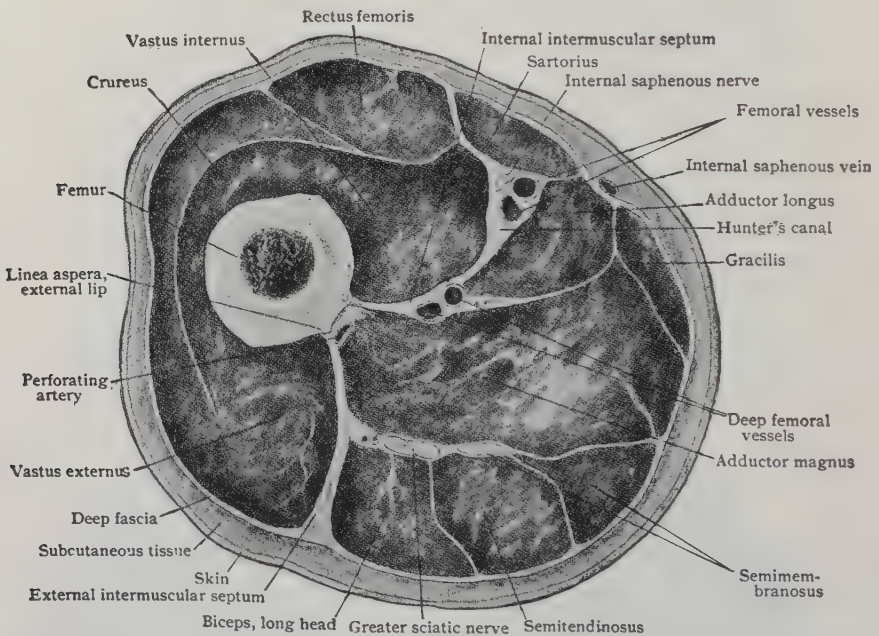

Fig. 1004.—Section across right thigh through Hunter's canal, seen from below. Note intermuscular septa and attachment to linea aspera. This section helps to visualize the great expanse of fascia in the whole thigh (Piersol, Human Anatomy, after Nifong).

Results following this method have been most satisfactory in Campbell's hands. Full motion of the knee has been obtained in adults in about six months (see Figs. 994–1000, inclusive).

Sixty per cent. perfect legs and 35 good results or 95 per cent. functionally satisfactory results from this method are recorded at present by Campbell.

Conwell's results by skeletal traction and the Pearson knee attachment to the Thomas splint have been satisfactory; 67 per cent. of his patients did the heaviest kind of work and 90 per cent. of these returned to the same work as before the injury.

Conwell avoids open reduction until a fair trial with skeletal traction and suspension has been carried out.

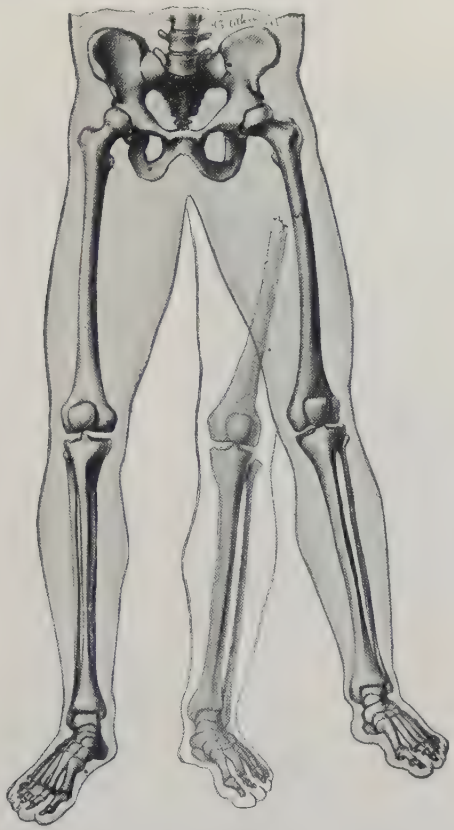

Fig. 1005.—Showing the necessity of abducting the injured leg in thigh fracture. In dotted line is shown the position likely to result from neglect of this abduction.

Fig. 1006.—Action of the muscular pull of the iliopsoas and of the external rotators in producing deformity in fracture of the femur high up. Upper fragment is flexed and abducted upon the trunk.

These cases of Campbell and Conwell may well represent the best to be obtained by non-operative expectant methods. They come near being ideal results. They form a standard to be emulated in non-operative work.

When the overlapping of over 1 inch cannot be held, when the fracture, therefore, cannot be approximated pretty accurately, when the end-to-end union is not readily obtained, I believe an open reduction is indicated.

See figures illustrating results of this method of immediate reduction and plaster-of-Paris splint immobilization.

Following such fracture table reduction by traction and manipulation the heavy thigh muscles tend to cause within the plaster-of-Paris splint a renewal of the displacement, no matter how perfect the reduction may have been, as shown by roentgenogram at the time of reduction (Eliason).

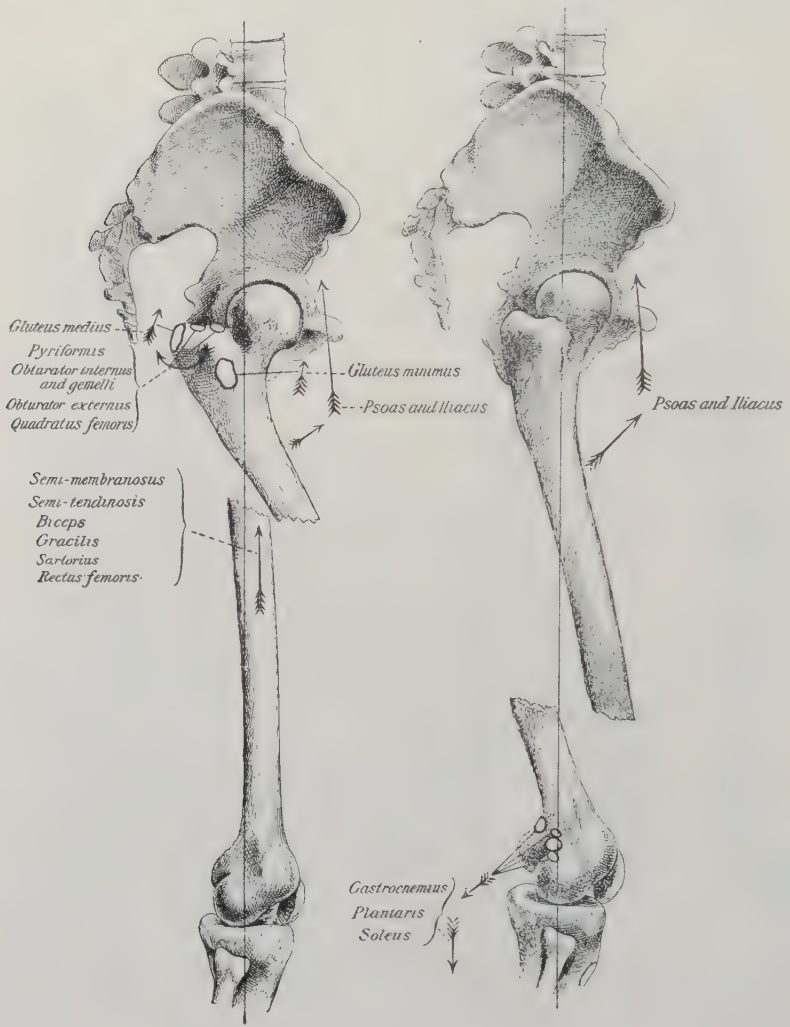

Fig. 1007.—Fractures of the shaft of the femur. Note the muscles active in the production of certain displacements (Deaver, Surgical Anatomy, after Nifong).

Even when the fragments of a transverse fracture of the femoral shaft have been interlocked, a bowing is extremely liable to develop from muscle action *within* the plaster-of-Paris splint.

Skeletal Traction.—By skeletal or direct bony traction is meant the application of the traction force to the bone (Chapter X, page 217).

This pulling upon the bone direct is far more efficient than is the old-time skin traction—30 to 50 pounds pull possible with skin traction.

The traction is applied either through a pin penetrating the whole thickness of the bone or through calipers or ice-tongs penetrating the cortex of the bone on two sides.

The advantages of bony traction are, briefly: the better control of the bony fragments; a less force necessary to effect reduction; it may be applicable immediately following the fracture, whereas open operation, if necessary, might require considerable delay if blebs and abrasions are allowed to heal; it allows of active joint motion; it is easily applied with the Thomas splint; sepsis is very unusual.

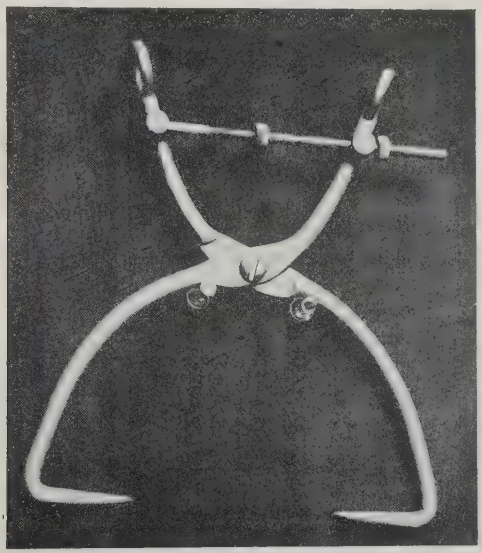

Fig. 1008.—The Z. B. Adams ice-tongs calipers for traction, as used at the Massachusetts General Hospital. This shows the ice-tongs made of ⅜-inch cast steel, upset a little, and flattened for the hinge. The lower arms are 7 inches long and bowed to fit the knee. The prong is an additional 2 inches and has an ice-tongs point. The upper ends are fitted with a threaded screw and two nuts which lock the tongs, preventing them from digging in or slipping off, if the weight should suddenly let go. The loop at the top is made by drawing the ⅛-inch steel out, and is for the attachment of the weight cord. The heavy steel is used to prevent the tongs slipping. Many forms of ice-tongs are manufactured.

Bony traction is to be employed only until the fragments are firmly held by callus. It is not to be maintained until union is secure.

It is important in the use of skeletal traction to apply at the outset the maximum traction force in order to secure at this most opportune time (immediately after the fracture) ready reduction of the fragments. When skin adhesive-plaster traction is used immediate early effective forcible traction is impossible except for a short time because of the slipping of the plaster.

The Thomas Splint, etc. (see Thomas Splint section, p. 208, for all details of selection, application, and uses of).—A long splint as seen in illustrations extending well below the foot should be used (see Fig. 1013). The ring should be well fitting. To estimate the size (the Thomas splint is supplied by instrument

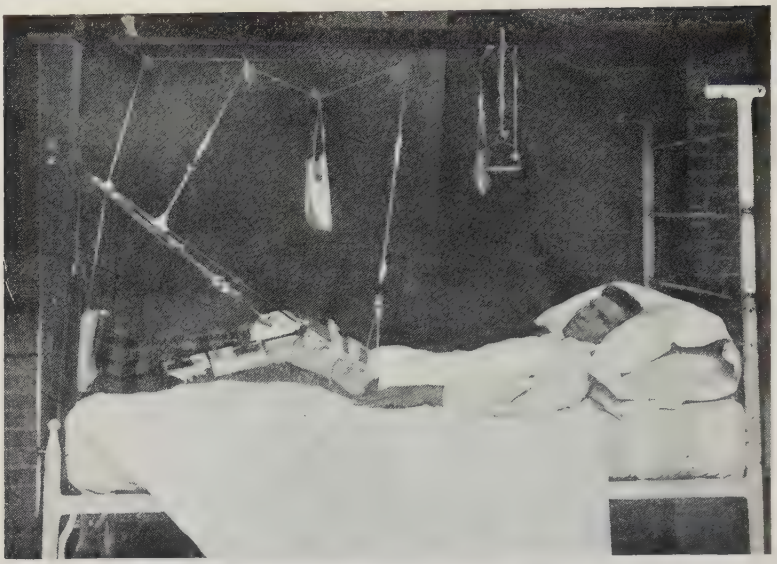

Fig. 1009.—Illustrating Z. B. Adams ice-tongs in use in a fracture of the left femur. Note Thomas' splint with Pearson flexion leg-piece. Note traction weight applied to the tongs and suspension of the Thomas splint.

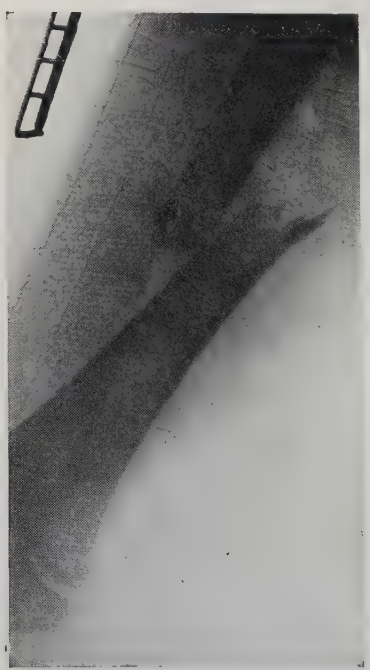

Fig. 1010.—Fracture of shaft of femur. Note sharp lower fragment.

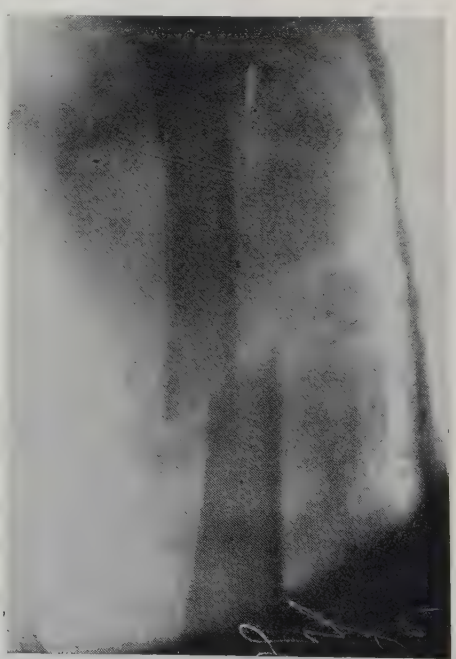

Fig. 1011.—Fracture of shaft of the femur. Note spike projecting from lower fragment. Same as Fig. 1010.

Fig. 1012.—Same as Fig. 1010. Note practically perfect anatomic reposition. Result perfect functionally. Incision and leverage without suture or plate accomplished this. Simple traction would not because of irregularity of bone fragments. Restoration of the line of the linea aspera determined by palpation determined the perfect position.

Fig. 1013.—Subtrochanteric fracture of the right femur. Note use of long Thomas' splint, without the Pearson knee splint. The traction by Steinmann nail through condyles of the femur and weight to foot of bed. Suspension of foot. Note slinging of other uninjured lower extremity in a Hodgen splint merely for comfort. Patient can lift his trunk by hand-grips. Ring of Thomas held to ischium by weight over pulley (Leland).

makers in regular sizes complete) required the transverse circumference of the thigh is taken in the upper third, and 2 inches is added to allow for the obliquity and the padding of the ring. The upright at an inch above the knee-joint should be bent to an angle of about 20 degrees unless the Pearson leg splint is used. Sinclair glue adhesive bands, as traction ropes, should be applied as high as possible. Double bands of flannel hammocks 4 inches wide for suspending the thigh and leg are provided.

A few details are stated here. For full account of Thomas splint and its use see p. 535.

Fig. 1014.—Compound fracture of both bones of the left leg. Comminuted fracture of both bones of the right leg. Note plaster-of-Paris splints on both legs. Window in plaster on left leg making exposure of compound wound easy. Both lower extremities suspended just off the mattress. Patient able to move trunk by hand-grips. This illustrates final stage in the treatment of these particular injuries (Leland).

In fracture of the thigh the flannel suspending band commences on the outer bar of the splint, is passed behind the limb, across the inner bar, and back again, and is fastened with a clip to the outer bar, where it started.

The leg should be supported well above the splint, *i. e.*, the upright of the splint should be a little behind the middle of the leg and thigh.

A right-angled foot-piece (see Fig. 971) may be adjusted or the foot suspended by weight attached to strips of flannel glued to the sole of the foot (see Figs. 940–942).

The adjustment of the fractured bones may be made by attention to the slings in which the limb rests, and by the placing of lateral pads (see Fig.

1497). The lower end of the splint should be fastened and supported to the foot of the bed.

The foot of the bed should be raised a foot or more if countertraction is to be secured by body weight (see Fig. 937).

The ring of the Thomas splint should be suspended by light weight so as to bring the ring into close contact posteriorly with the ischium (see Figs. 948, 1013). Inspection of the apparatus must be made daily with considerable care.

Provision should be made for the mobility of the joints adjoining the fractured bone; especially is this true of the hip-, knee-, and ankle-joints.

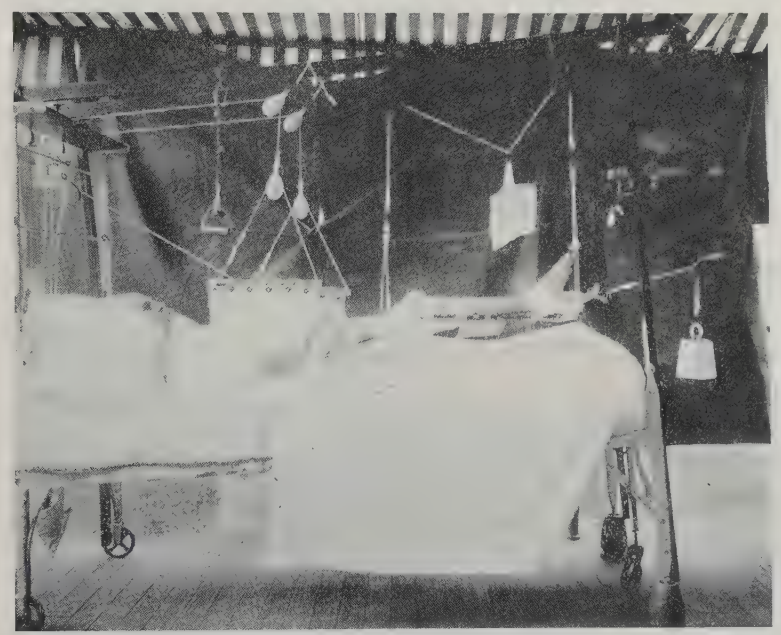

Fig. 1015.—Fracture of both bones of leg at junction of lower and middle thirds. Separation and displacement at the symphysis pubis. Note application of Steinmann nail through os calcis, traction 10 pounds direct. Suspension of whole lower limb. Note particularly suspension of pelvis in hammock to assist in immobilization of symphysis and care of patient (Leland).

The stiffness of the knee following fracture of the femur treated by older methods is often more disabling than the fracture itself.

Any appliance used in treating fracture of the femur should allow of massage and movement of the knee- and ankle-joints. This requisite is met in the use of the Thomas, Blake, Hodgen, and Hawley splints when combined with the Pearson hinged knee flexion appliance (see Figs. 1009–1022). (See details of Thomas splint, etc.)

Special Conditions to Be Considered in the Treatment of Fracture of the Femur.—Treatment in general of the fractured femur will be directed to the prevention of:

1. Shortening of the injured limb. The muscle contraction and especially

Fig. 1016.—Compound fracture of both bones of the leg, late stage. Simple retentive splint. Note arrangement of suspension on Scudder suspending bar. Hand-grip for assisting in flexion at knee and moving body (Leland).

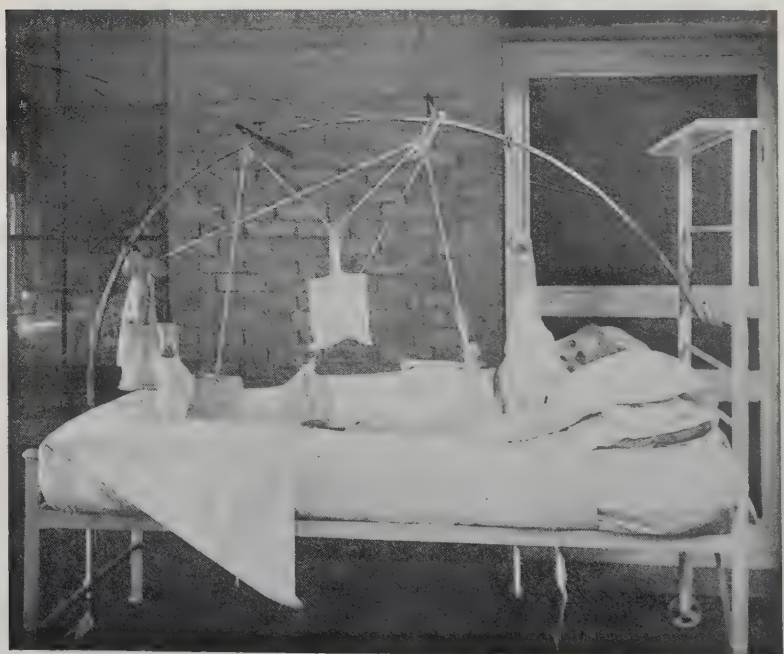

Fig. 1017.—Fracture of the neck of the left femur. Scudder suspending bar. The fracture reduced by the Whitman maneuver and held by a plaster-of-Paris spica. Note suspension of abducted lower extremity and trunk. Hand-grip permitting lifting and moving trunk (Leland).

the retraction of the great planes of fascia prevent reduction. A sufficiently heavy weight applied early to the distal fragment will overcome shortening.

Fig. 1018.—The Finochietto stirrup (The Kny-Scheerer Corp.).

Fig. 1019.—The Finochietto stirrup (The Kny-Scheerer Corp.).

Ordinarily 15 or 20 pounds will be needed in the adult. Comparative daily measurements of the extremity and *x*-ray plates will determine the efficacy of the weight used.

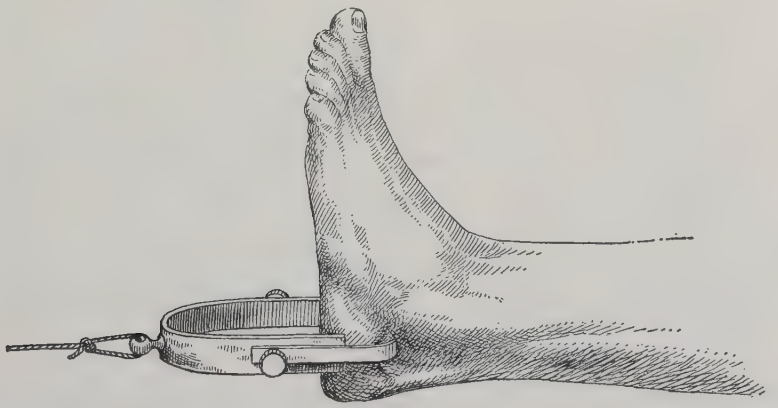

Fig. 1020.—The Finochietto stirrup. Showing its mode of application, the band passing just in front of the tuberosity of the os calcis (Blake).

2. Outward bowing at the fracture site. Abduction of the extremity carrying the distal fragment outward will correct outward bowing (see Figs. 1003, 1005).

If the abduction and flexion of the upper fragment is extreme, it may be found wise to use two Thomas splints abducting the well extremity to im-

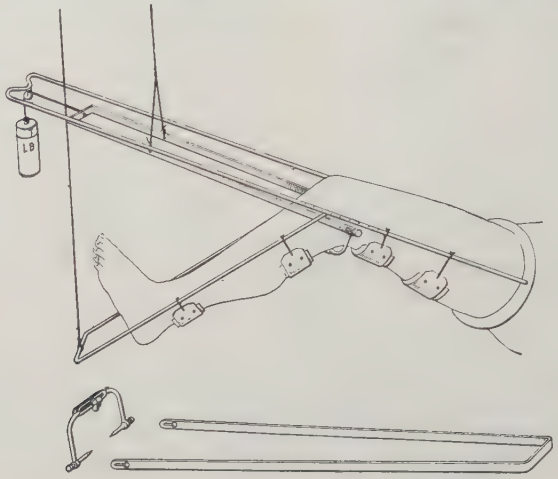

Fig. 1021.—Watkins-Williams' caliper with traction bars. The traction is made not on the loop, but on the ends of pins direct by means of the extended looped bar so as to allow of full knee extension. Note the employment of this caliper with the Thomas splint (Hawley).

mobilize the pelvis. Greater efficiency will thus be secured in the abduction of the injured side.

3. Permanent rotation of the leg and thigh below the fracture. This rotation is usually outward and is shown by eversion of the foot. When

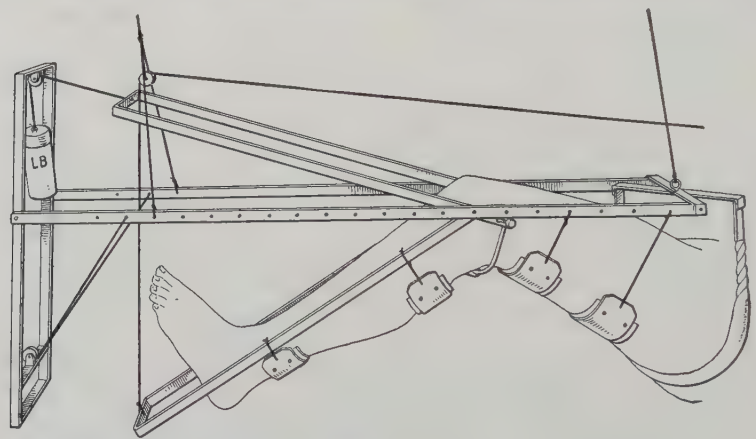

Fig. 1022.—Hawley splint for fracture of thigh. Note suspension of thigh ring. Pearson leg-piece adjustment of thigh ring to ischium. Slinging of limb in aluminum cups, Watkins-Williams' caliper and traction bar. This arrangement permits of knee motion from flexion to complete extension under the contro l of the patient (Hawley).

the ordinary Buck's extension is used, a bandage fastened below the calf of the leg to the posterior bandage or ham splint, brought up on the outer side of the leg and fastened to the long outside upright or to the cradle, will keep the whole limb from rolling outward (see Figs. 1001, 1002).

Fig. 1023.—Non-penetrating calipers applied. (Pearson's modification of Besley's.) Note attachment of cord. The white area on the bone is covered by synovial membrane of the knee-joint (Pearson and Drummond).

Fig. 1024.—Lateral view of Fig. 1023 (Pearson and Drummond).

4. Sagging backward of the thigh (Fig. 1003) or slumping of the thigh is prevented by lifting the middle of the thigh forward by proper support through padding on the ham splint, and by the sling of a Thomas splint.

The mobilization of the knee and ankle must be carefully provided for.

Fig. 1025.—Non-penetrating calipers after sixteen weeks *in situ*, close to a large and very septic fracture. No pain or sepsis at caliper points throughout the treatment (Pearson and Drummond).

Fig. 1026.—Unnecessary penetration of the points of the calipers before modification of the instrument (Pearson and Drummond). Too low application.

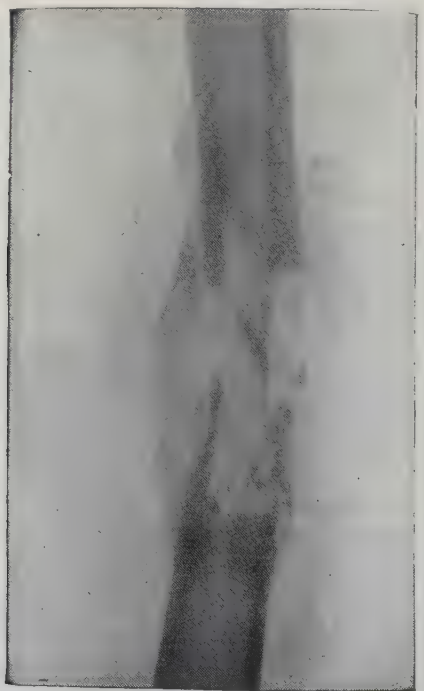

Fig. 1027.—Filling in of partial gap. Recovery with good union, no shortening. Note great comminution of fragments (Pearson and Drummond).

The treatment of the fracture of the femur, whether of the *upper third*, with its characteristically abducted and flexed short upper fragment, or of the *middle of the shaft*, with the special difficulty of great shortening and possible non-union, or of the *lower third* of the shaft, with the always troublesome posterior displacement of the distal fragment, the treatment will be decided according to the method best adapted to the situation in the fracture under consideration.

Fig. 1028.—Four-inch gap occupied, after sequestrectomy, by fine débris only. Recovery with 0.5 cm. shortening (Pearson and Drummond).

There are available the following methods of treatment:

1. Immediate reduction with plaster-of-Paris fixation, with or without permanent traction, and suspension of the plaster splint.

2. Adhesive plaster or glue traction through the skin with the Thomas suspension splint (or an equivalent splint).

3. Skeletal traction with Thomas suspension splint (or an equivalent splint). Using in both (2) or (3) appropriate positions of the distal fragment.

4. Operation: Direct replacement and fixation.

Discussion on the Choice of Treatment in a Fracture of the Shaft of the Femur in the Adult.—The important determining factors in the final selection of the treatment of a closed fracture of the femoral shaft in an adult will be: (1) the elapsed time since the accident; (2) the character and location of the fracture; (3) the understanding by the surgeon in charge of available methods.

When seen immediately after the accident reduction of the fracture is to be tried by means of a general anesthetic, traction, manipulation, and immobilization. Immobilization may be secured by using traction and suspension in a Thomas splint or by plaster-of-Paris spica (Campbell, p. 550).

Intertrochanteric fractures, occurring most often in active adults, present marked shortening and the angle of the neck with the shaft definitely diminished, sometimes to a right angle. Strong traction and abduction will restore the length of the bone and the angle of the neck. This position may be held by skin or skeletal traction and the Thomas splint. Convalescence for several (six) months on a walking caliper will preclude a coxa vara.

Fig. 1029.—Oblique subtrochanteric fracture of shaft of femur (*x*-ray).

Fig. 1030.—Spiral fracture of the shaft of the femur high up (*x*-ray tracing).

Fracture of the Lesser Trochanter of the Femur.[1]—The largest number of these fractures occur between about ten and twenty years of age. It is unusual. There are but about 25 cases recorded in medical literature. A diagnosis of fracture of the neck of the femur was made in 3 of these cases, so much did the symptoms and signs resemble this fracture.

[1] Boston Brit. Jour. Surgery, vol. ix, p. 256, 1921, 1922, Langdon.

It is ordinarily due to muscular avulsion, in an effort of the iliopsoas to restore body equilibrium when being suddenly thrown forward or backward. There is tenderness in Scarpa's triangle. There is inability to flex the thigh while in the sitting position (Ludloff). There is acute pain in Scarpa's triangle and at the inner third of the gluteofemoral fold. Treatment will be fixation of the thigh in a flexed position, outward rotation and abduction for at least two weeks, and gradual moving about at first with the aid of

Fig. 1031.—Patient fifty-five years old. Intertrochanteric fracture of the femur before traction was used. See Fig. 1032. Note levels of the obturator foramen and the lesser trochanter (Harmer).

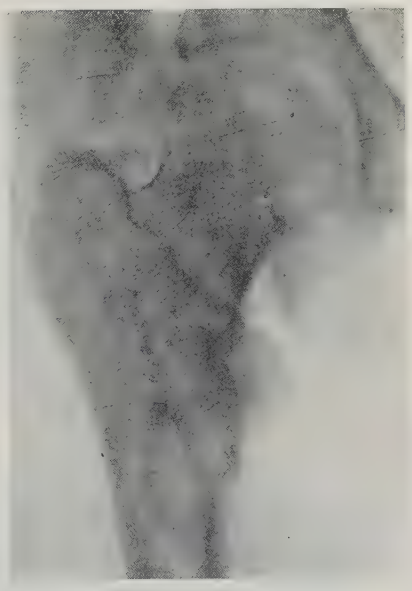

Fig. 1032.—Patient fifty-five years old. Same case as Fig. 1031. Intertrochanteric fracture of the femur. After initial traction 28 pounds has been used in a Thomas splint. Result four years after treatment. No limp, no pain, no stiffness of knee or hip, uses no cane, has resumed all activities as before accident. Note the levels of the obturator foramen and lesser trochanter. Compare levels before traction and after traction. The result indicates the efficiency in this type of fracture of traction and countertraction (Harmer).

crutches. An *x*-ray will disclose the exact lesion. Good functional results follow in both old and young.

Fractures of the *upper end of the femoral shaft:* Treatment by continuous traction and suspension with a Thomas or Hodgen splint, so placing the distal fragment as to best meet the proximal fragment and using sufficient continuous traction to correct the shortening. If reposition is impossible after seven to ten days' trial, operation should be done.

Certain fractures of the *shaft of the femur* may be aligned and held approximated with insignificant shortening by continuous suspended skin or skeletal traction, with flexion of hip and knee.

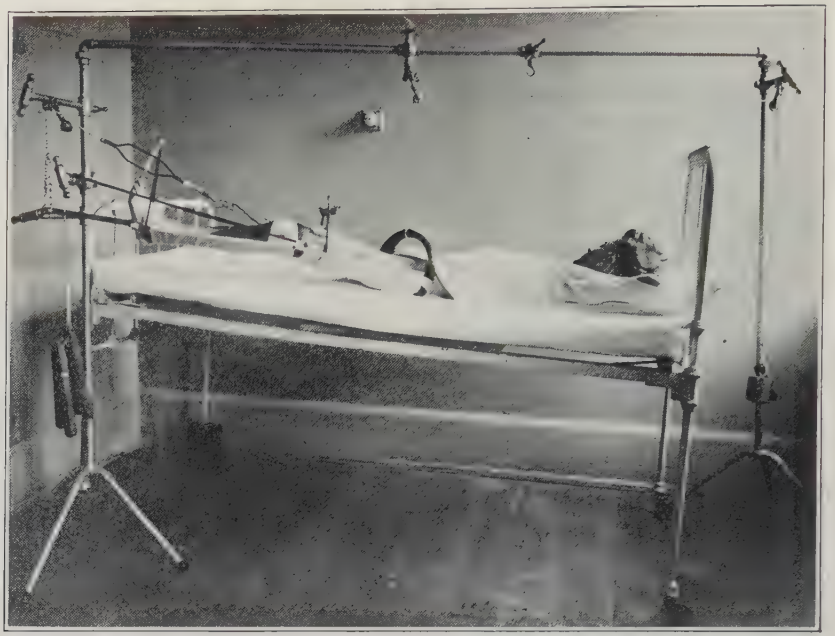

Fig. 1033.—Thomas splint and knee flexion piece suspended to the Morrison overhead frame, with caliper traction. The method of suspension of the leather ring to secure fixed countertraction is shown (L. C. Abbott).

Fig. 1034.—Thomas splint, knee flexion piece, suspended to overhead caliper traction, screw pressure pad attached to a half-ring in order to correct anterior lateral displacement of the fragments (L. C. Abbott).

The *supracondylar fracture* may require right-angle flexion of hip and knee with skeleton traction to overcome displacement of the fragments, using the Thomas splint and Pearson knee attachment.

If caliper traction is used, the caliper is applied a little above the frontal plane of the femoral shaft (Fig. 299), so as to tend to lift the upper end of the short distal fragment dorsally into place. Pressure upward may be made by the lowest sling. The knee is slightly flexed so as to relax the gastrocnemius insertions.

The use of Hoglund's caliper will likewise tend to lift the distal fragment forward (Fig. 302). The pull of the caliper in the straight line of the femur draws the lower fragment down into position, and the caliper points being on diametrically opposite sides of the bone, this straight pull usually corrects lateral tilting. Should lateral tilting prove obdurate, there are two devices for dealing with it. Either (1) take the cord from the caliper round a lateral pivot on the splint and thus produce leveraging of the lower fragment; or (2) attach the knee-flexion splint obliquely, higher on one side than on the other, and direct the pull on the calipers in the line of the flexion piece.

The quadriceps tendon, made taut by flexion of the knee and the pull of the weight, acts as a splint on the front of the fracture. Tilting forward of the lower fragment does not occur unless the calipers are applied far forward.

Fractures Into the Knee-joint.—Fractures entering the knee-joint in the adult, T and Y, fractures separating a condyle of the femur are best treated ordinarily by direct reposition by operation. Obviously, immediately following the injury attempts may be made of manual reposition of fragments by placing the extremity in the position of relaxation and physiologic rest (flexion of hip and knee) and suspending the leg in a Thomas splint, with a Pearson adjustable leg addition, with or without traction, as may seem wise. The above treatment for six or seven days will help to determine whether something may be accomplished by external lateral pressure (p. 741) with Scudder's clamp. The lateral pressure through the caliper may assist in the reduction. If pretty exact obliteration of the joint deformity cannot be brought about, then direct operative treatment should be at once used.

The week of non-operative tentative treatment will not have been in vain, for during this period preliminary preparations for operation will have been carried along.

Cases of fracture of the femur which after careful study obviously cannot be replaced by immediate traction and manipulation, and cases seen too long after injury (delayed cases) for immediate reduction (three weeks possibly) should be treated by prolonged continuous traction and suspension or by operation, and, if necessary, direct fixation.

Fractures of the upper and lower thirds of the femur which are likely to resist forcible traction and reposition should be replaced by operation.

Certain *transverse fractures*, whose fragments cannot be approximated because of muscle interposition, should be operated upon.

Certain transverse fractures having a *projecting spike of bone* or several projecting spicules of bone which hinder reduction should be operated upon (see Figs. 1010–1012).

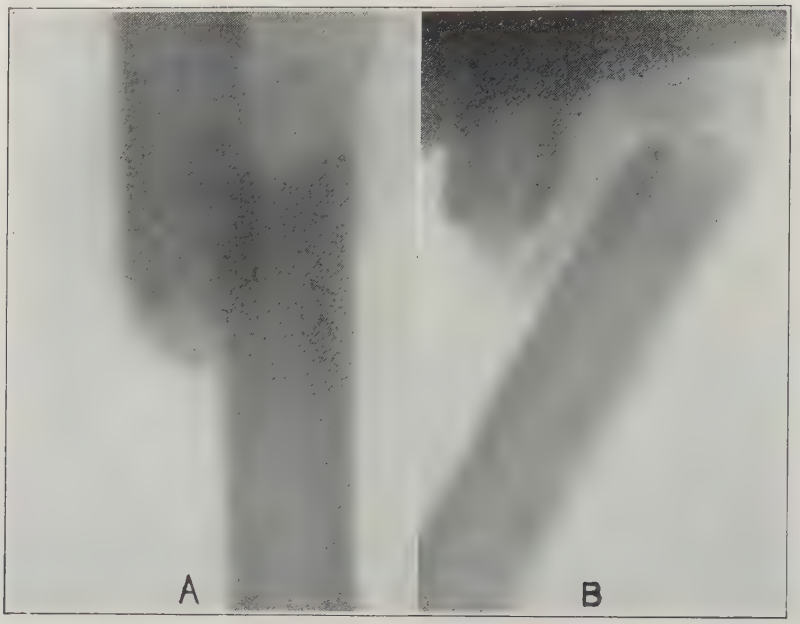

Fig. 1035.—"Case 4." Appearance of fracture (August 22, 1921). A, On admission showing overlapping of fragments and considerable callus. B, Lateral view showing angulation of fragments. (L. C. Abbott.)

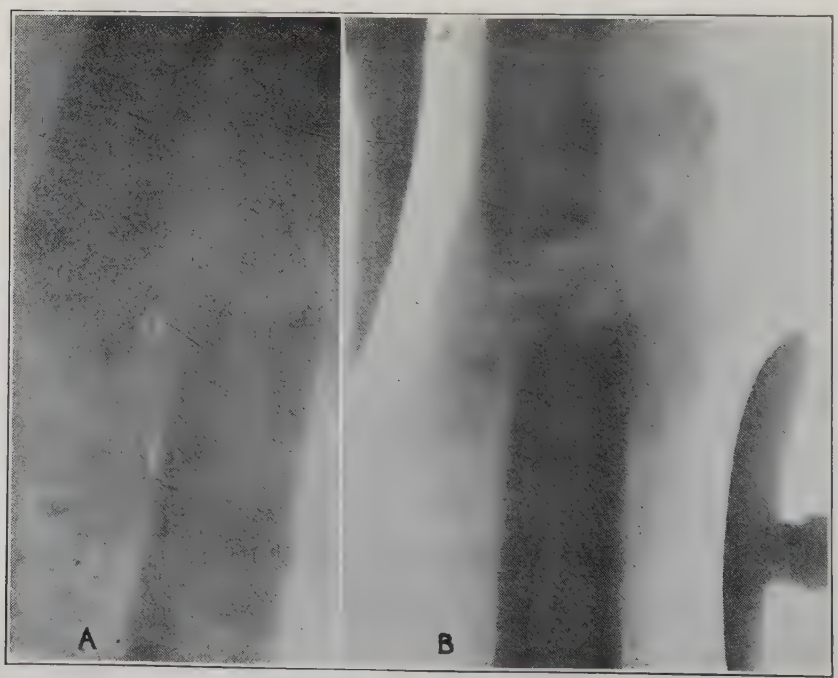

Fig. 1036.—"Case 4." Appearance of fracture: A, Position of the fragments (September 9, 1921), after manipulation and caliper traction. B, Correction of lateral displacement by pressure pads. Note shadow of pressure pad at right. (L. C. Abbott.)

Certain long *oblique* mid-shaft fractures seen too late for immediate handling should be operated on.

The limitations of traction and countertraction, of manipulation and pressure, together with suspension as the adequate treatment of fractures of the shaft of the femur are gradually coming to be understood. As these limitations are better known much unnecessary experimental manipulative treatment will be abandoned. The successful adequate method of treating a given fracture will be selected at the outset with confidence.

There will always be fractures offering unique and difficult problems in treatment. There will always be slight variations from the absolutely normal anatomical and perfect functional results in both the ideally applied and

Fig. 1037.—"Case 4." Final result (December 22d). Union solid, alignment perfect (L. C. Abbott).

completed non-operative treatment and in the happily chosen and finished operative treatment.

These facts make it incumbent on the surgeon to study all the conditions of the case at hand, to be familiar with possible methods of treatment, to choose that method which appears to be the most effective.

The Operative Treatment of Fracture of the Shaft of the Femur (p. 753).—With the skilled use of direct bony traction at the outset of treatment the need for direct operation upon the femoral shaft fractures should be less.

If after a reasonable attempt to correct displacement and shortening by traction it is found impossible, then the displacement should be corrected by aid of an incision, traction, and direct leverage (see p. 756).

Huntington's method of traction and countertraction illustrated in Fig. 1046 is helpful at the time of operation. Martin's method of direct traction on the distal fragment is to be recommended in fractures with great overlapping of fragments.

The After-treatment of Fracture of the Femur and the General Management of Fracture of the Femur.—I quote from Pearson and Drummond, as they have admirably described in great detail the many steps in the after-care of fracture of the shaft of the femur treated by non-operative methods.

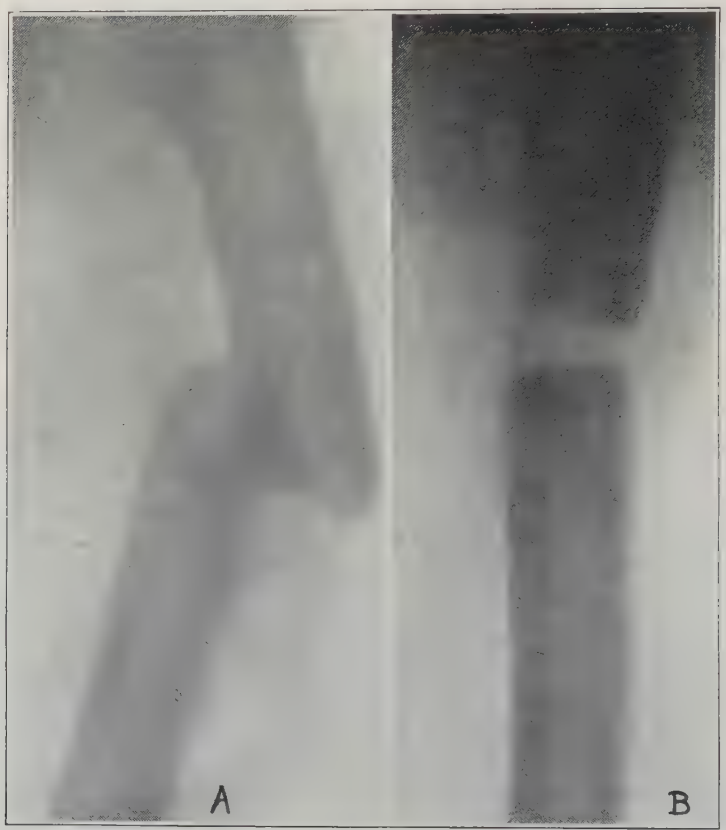

Fig. 1038.—"Case 6." Appearance of fracture: A, On admission (March 14, 1921), showing ununited fracture, with angulation and overlapping of the fragments. B, After manipulation and caliper traction (March 25th). Note especially the correction and overriding of fragments. (L. C. Abbott.)

Success in the management of all fractures, and especially in femur cases, depends on the amount of care bestowed on them. No method will give uniformly good results except by constant attention to the details of its management. No method allows the surgeon to dispense with close personal attention, which must be very frequent in the early stages. The nurse's part is of the utmost value, so is that of the masseuse, but unless the surgeon knows the difficulties of both his ultimate results will be poor.

In the first place the surgeon should remember the importance of delicacy of touch and movement. Rough handling during dressings is a crime. Bumping against beds is clumsiness excusable only in the untrained. The actual control of the fracture will entail a considerable amount of work on the part of the surgeon.

By inspection, palpation, radiography, and measurement he will get complete information as to his success or otherwise in correcting disability or deformity.

Fig. 1039.—"Case 6." Appearances after application of bone plate (March 30th) (L. C. Abbott).

He will find that in many cases he has to make alterations in the positions into which the limb was originally put. In most cases at first he will have to make daily minor adjustments.

The adjustments consist of increase or decrease of abduction or adduction, more or less flexion of joints, tightening of posterior slings, progressive use of pressure pads, attention to cord and pulley, etc.

Above all, it is his special duty to carry out the daily movements of the knee-joint. It is Pearson's practice, and I approve this practice, to begin this on the earliest possible day after the injury, *i. e.*, immediately the patient is fitted with his permanent splint, knee flexion attachment, and caliper extension.

Assuming that the case is a recent one, one should begin by lowering the foot 1 or 2 inches a day until the heel reaches the bed, by which time the

Fig. 1040.—"Case 6." Appearance of bone after plate has been removed (November 22d), showing union and good alignment (L. C. Abbott).

knee will have been flexed through, say, 40 degrees. This may take a week. One should then work upward 1 or 2 inches a day until the upper limit is reached, after which wide movements can be carried through every day. These movements should not be delegated to others and must be done regularly and adequately. If the knee is left unmoved for a week at a time some mobility will be lost and will have to be regained gradually. Later, when traction calipers have been discarded and some union has occurred, the movement

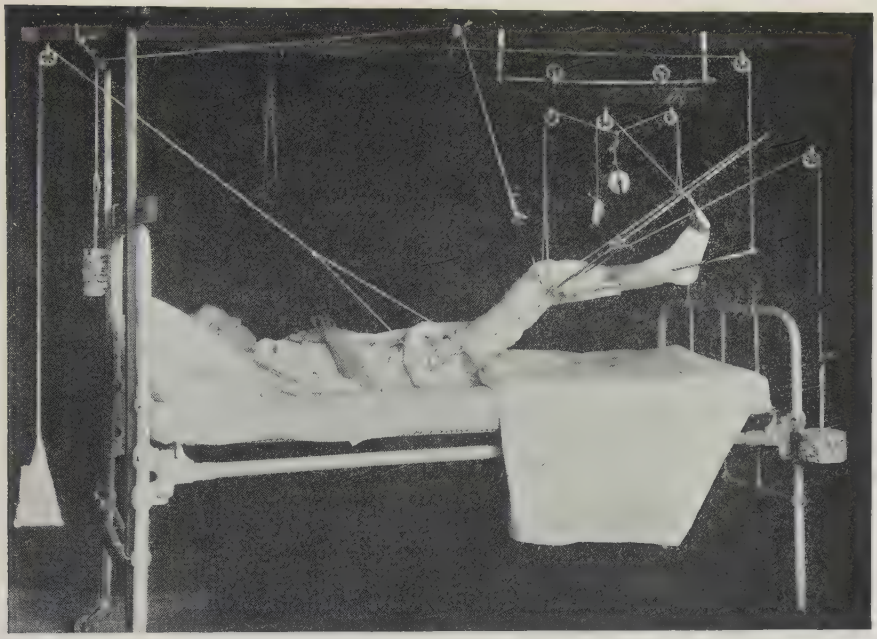

Fig. 1041.—Supracondylar fracture of femur. Thomas splint with knee flexion attachment. Calipers to condyles of the femur and to the head of the tibia. Note especially the lift obtained by the vertical pull on the upper end of the lower fragment by tong suspension (H. E. Santee).

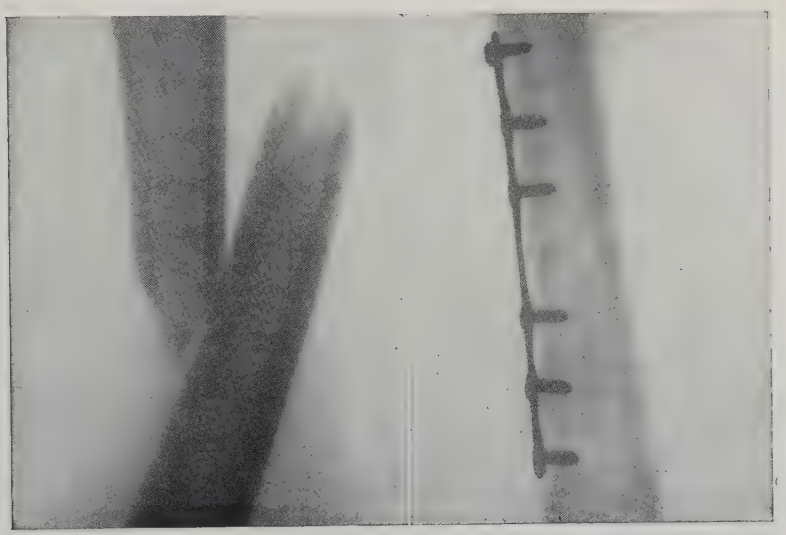

Fig. 1042.

Fig. 1043.

Fig. 1042.—Fracture of the shaft of the femur. Considerable shortening. Muscle interposition preventing reduction.

Fig. 1043.—Same as Fig. 1042. Incision, reposition, and steel plate applied with six screws as a temporary measure. Plate removed after about four or five weeks. A perfect result anatomically and functionally. Heavy *immediate* traction in a Thomas splint (or one of similar type) might replace this fracture if bony irregularity and muscle did not interfere.

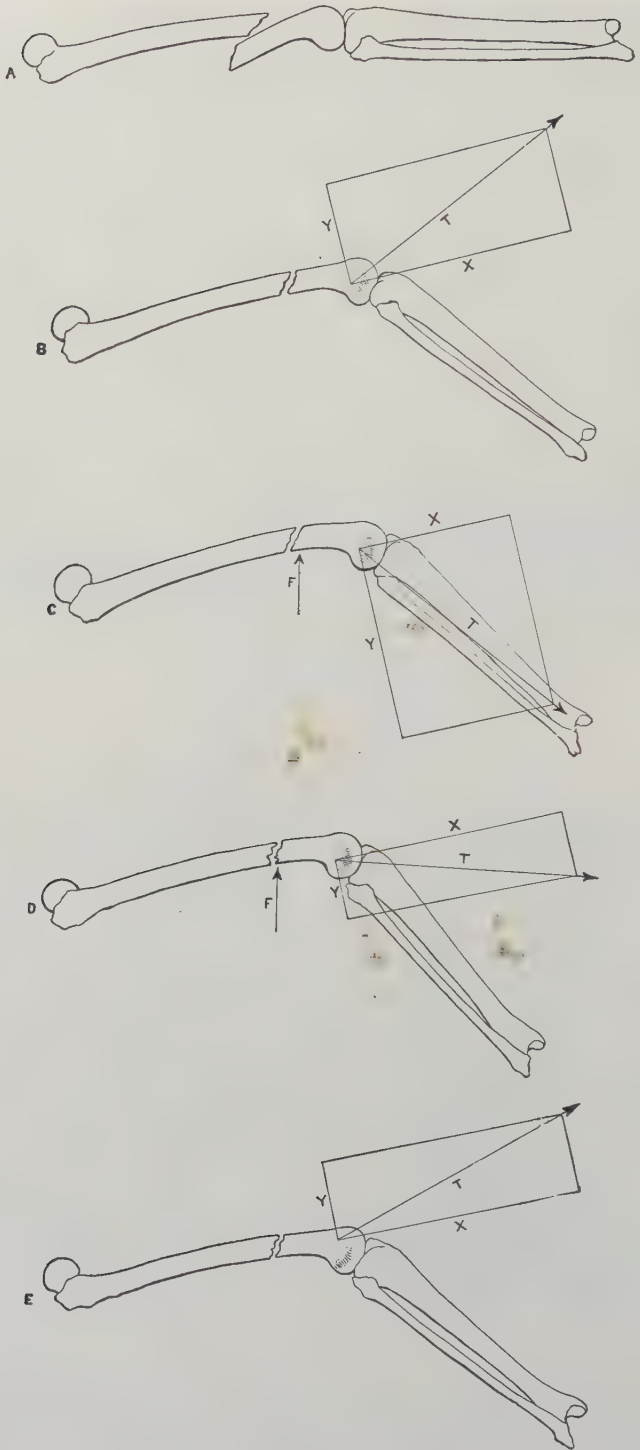

Fig. 1044.

of the leg can be relegated to the patient. Movements of the ankle and toes must be attended to also.

x-Rays should be taken at necessary intervals to be sure of the progress made in the conduct of the case.

Inspection of the fractured limb should be made at least daily. Measurement should be made twice a week during the first few weeks and recorded (Pearson), the internal malleolus being reached through the bandage. Parts of the apparatus may need changing, and straps may require tightening or loosening. The heel and sacrum will require attention because of the constant pressure from lying in one position. Suspension of the limb will diminish danger of pressure.

Ordinarily there will be little or no pain associated with the repair of the fracture. After about four weeks all apparatus should be removed and the limb thoroughly inspected, to detect, if possible, any uncorrected deformity, and to determine whether union is yet firm. In from four to six weeks repair in a healthy child or young adult should have advanced to the stage of firm union. Ninety-seven per cent. of fracture of the shaft of the femur in patients under ten years of age will be united within seven weeks (Paul). The apparatus should then be reapplied. At the end of the eighth week all apparatus should be finally removed. The thigh should be washed and thoroughly oiled. The patient should be permitted to lie in any position in bed without retentive apparatus for one week. The patient should not be allowed to bear weight upon the unprotected thigh until after the ninth week. At the ninth week he should be allowed up and about with crutches, and a moderately high-soled shoe (2 inches) should be worn upon the foot of the uninjured thigh. He should bear no weight upon the injured leg. The seat of the fracture should be protected by coaptation

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Fig. 1044.—The usual deformity in fractures of the lower third of the femur and the disposition of the forces to overcome it. In the diagram T = traction; X = lengthening force; Y = lifting force; F = support or fulcrum. A, Showing flexion of the distal fragment and overlapping. If not overcome, the sharp end of this fragment may perforate the skin. B, Illustrating tong traction applied higher than usual to lower part of shaft just above the condyles. Traction is made in an upward direction as compared with the axis of the proximal fragment. It is evident that the lifting component is increased and the lengthening component diminished when the point toward which traction is made is raised. In this case the points of the tongs are the fulcrum and the fragment is tilted into position by the weight of the leg and foot depressing the condyles. In practice the line of traction should at first be made to coincide with the axis of the proximal fragment, and as soon as overlapping is reduced, raised to increase Y and overcome the angular or vertical deformity. C, Illustrating skin traction and also tong and pin traction when applied to the tibia as well as stirrup traction to the os calcis. Traction in this case is always in the axis of the tibia and is transmitted to the distal fragment of the femur through the lateral ligament of the knee, and, therefore, the site of its application corresponds to their attachment to the condyle. As before, the traction force may be divided into two components, a lengthening X and in this case a depressing Y which vary with the degree of flexion of the knee. To offset Y the supporting bands are kept tight under the distal fragment and constitute the fulcrum F. In practice, traction at the outset should be made with the leg almost extended until the overlapping is overcome, when the leg should be flexed until the vertical displacement is reduced. D, Illustrating tong traction applied to the distal fragment, but instead of the principle described in B, that described in C is utilized, namely, that of making traction in a line below the extension of the axis of the proximal fragment. It differs from C in that the degree of flexion of the leg has no influence upon the position of the distal fragment. Therefore by this method the greatest freedom of motion of the knee is permissible. E, Illustrating the method proposed by Van der Veld. The tongs are placed as far forward as possible on the distal fragment, and traction is made in or above the axis of the proximal fragment. The articular surface of the tibia being held opposed to that of the femur by the fascia lata and muscles of the thigh as well as, perhaps, to a certain extent by the attachment of the leg to the splint, a fulcrum is developed at the articular surface of the tibia and the forces may be resolved into one X, the lengthening force, and another Y, tending to rotate the fragment upward. (Blake.)

splints and straps or a light spica plaster-of-Paris bandage from the toes to above the waist. A Thomas splint, a walking caliper splint, fitting into

Fig. 1045.—Fractured femur, base of neck driven into the shaft. Spiral fracture of shaft just below this (Warren Museum, 6529).

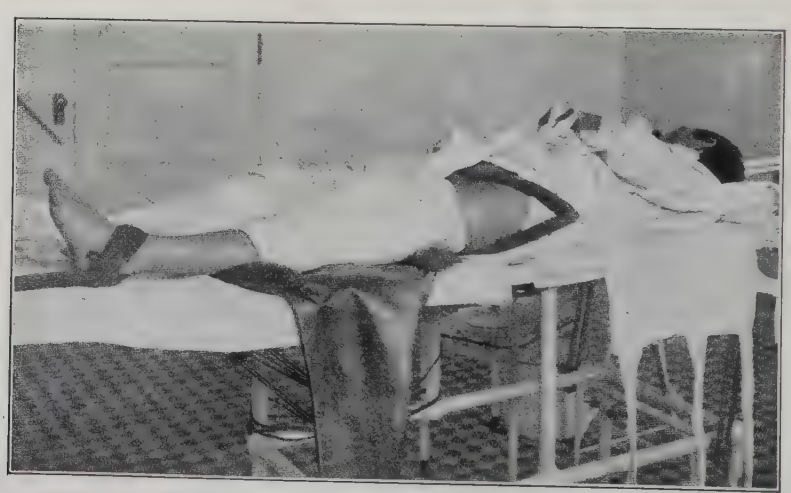


Fig. 1046.—A traction and countertraction method for use in fracture of the shaft of the femur during operation (after Huntington).

the sides of the sole of a shoe, makes an inexpensive and easily handled protective splint (see Fig. 1051). This may be used in the fracture of the femur

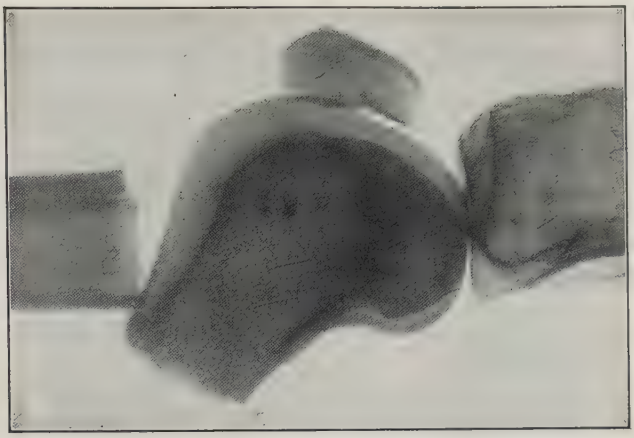


Fig 1047.—Low transverse fracture of the shaft of the femur. Displacement of the lower fragment backward by the gastrocnemius muscle (see Fig. 1048) and of the upper fragment forward. Overlapping of fragments.

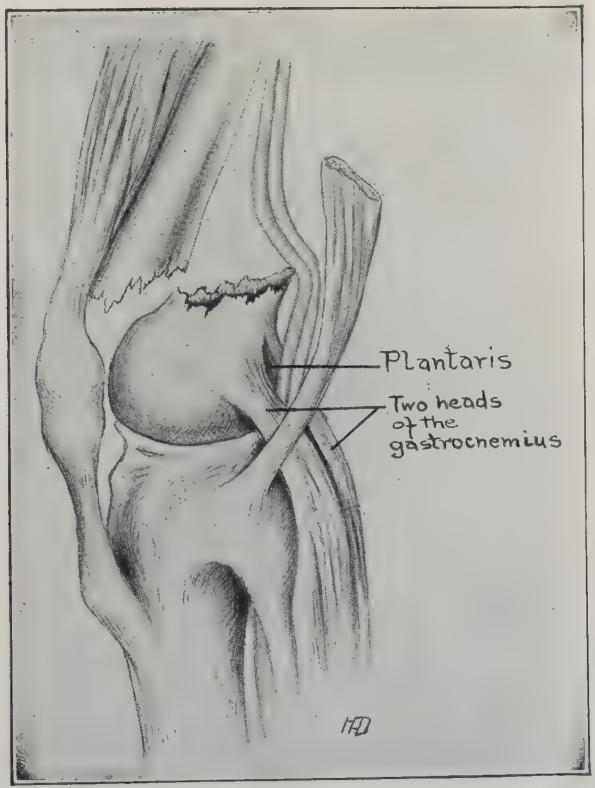


Fig. 1048.—Supracondylar fracture of the femur. The lower fragment drawn backward by muscular contraction. The vessels may be damaged by the upper edge of the lower fragment (after Nifong).

at whatever portion it is broken after union is firm. The support afforded by this splint enables the patient to move about and protects the recent fracture from too early weight bearing. The general health is thereby improved

and lateral bending at the seat of fracture is prevented (Fig. 1005). At the end of three or four months all support may be discarded, and the adult

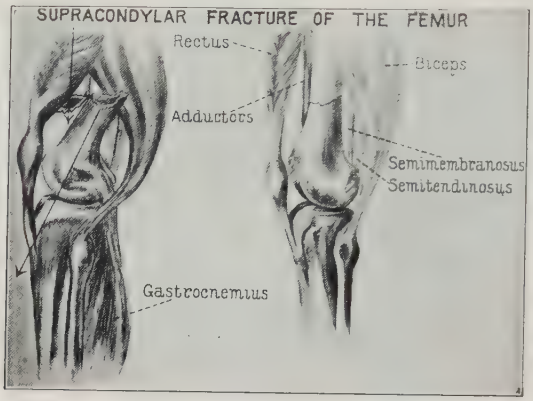


Fig. 1049.—Supracondylar fracture of the femur. Note displacement and perfect reposition (Henderson)

patient encouraged to gradually bear his weight upon the injured limb. The careful surgeon will be sure that the walking caliper splint (Figs. 1050

Fig. 1050.—Thomas walking caliper splint and shoes (see Fig. 1051). Note addition to sole of shoe of well foot (Pearson and Drummond).

and 1051) fits accurately, is comfortable and efficient, and is worn as directed for such time as the type of fracture and the patient's bony reaction demand. With this security one is sure that secondary deformity will be avoided, as

well as shortening and displacement of screws and internal fixation apparatus, if *in situ* at this date. Eighty-three per cent. of all fractures of the shaft of the femur, including those in adult life and childhood, were *solidly* united within nine weeks (Paul). Of course fractures of the femur vary considerably in the time the patient is able to get about, but the foregoing routine is that of average uncomplicated cases.

It is desirable to avoid the disability of the knee-joint which invariably accompanies fractures of the neck and shaft of the femur. To the accom-

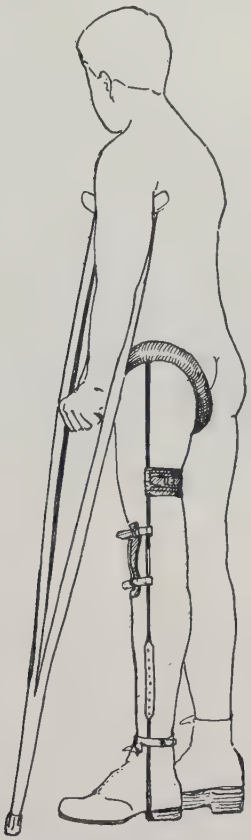


Fig. 1051.—Thomas caliper splint: The lower ends of the splint fit into the heel of the shoe, and part of the body weight is transmitted to the ground by the direct thrust of the rings against the tuberosity of the ischium (see Fig. 1050). The opposite shoe should be slightly elevated (M. G. H. Conference).

plishment of this end attention is directed to the incorporation in the plaster-of-Paris splint of an adjustable splint of metal (Leland).

Metal bands about the thigh and calf connected by steel uprights, which are hinged opposite the knee, serve this purpose. Early active and passive motion and massage are thus so facilitated that the ordinary stiffness of the knee-joint is in some measure eliminated (Figs. 1373, 1374).

The *convalescent treatment of fracture of the thigh* by means of the long Taylor hip traction splint, a high sole upon the shoe worn on the well foot,

Fig. 1052.—Fracture of shaft of femur. Note great displacement and consequent deformity. See Fig. 1053 of an entirely different patient, similarity of deformity noticeable.

Fig. 1053.—Lateral view. Oblique fracture of the shaft of the femur low down. Little backward displacement of lower fragment. Considerable shortening of thigh from forward displacement of upper fragment. Man aged forty. Recovery (*x*-ray tracing). There being no fracture into the knee-joint this would be ideally treated by bone caliper direct traction.

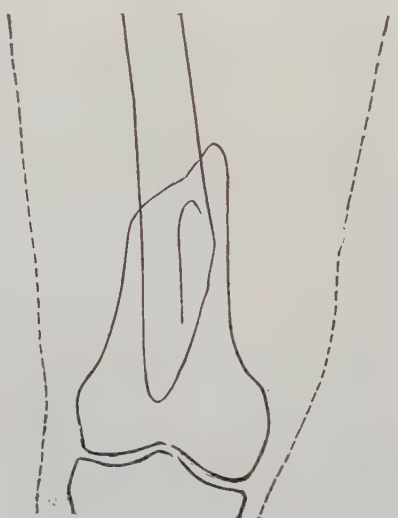


Fig. 1054.—Same as Fig. 1053. Anteroposterior view (*x*-ray tracing)

and crutches, is of very great value, especially in children and young adults (see Figs. 1058, 1059). The hip-splint, consisting of a long outside upright,

Fig. 1055.—Oblique fracture of the shaft just above the knee, with splitting apart of the two condyles. Extreme displacement; necrosis of tip of upper fragment. Patient, a man of thirty-seven years, lived for five months (Warren Museum, Specimen 1118).

pelvic, thigh, and calf bands, is applied with two perineal straps (Figs. 1058, 1059). The traction is made through the windlass at the foot-piece after

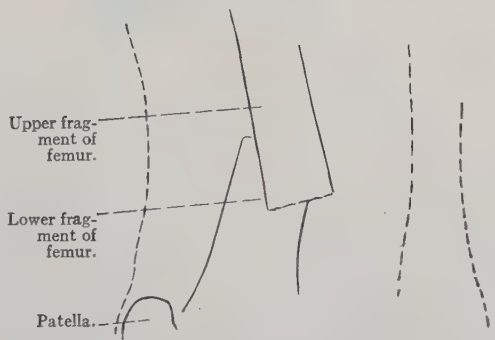


Fig. 1056.—Transverse fracture of the femur in the lower third with backward displacement of both fragments. Lateral view (*x*-ray tracing).

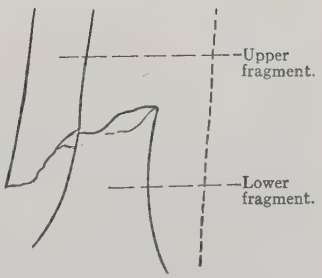


Fig. 1057.—Same as Fig. 1056. Anteroposterior view, showing lateral displacement.

fastening the extension strips to it. The countertraction is made by the two perineal straps. The thigh is securely held by coaptation splints and a

bandage about the thigh and splint. The patient goes about with crutches and a high sole of 2 inches upon the shoe worn on the well foot, bearing a little weight upon the foot of the splint. As a matter of fact the real value of this method in fracture of the thigh lies in the improvement to the general health by the early getting into the upright position and out of bed. This application of the ambulatory splint certainly is of great comfort to the patient. That it hastens the reparative process is yet to be fully demonstrated. If the Taylor hip-splint is used, it should be applied when union is found to be firm. After wearing the splint in bed for a few days the patient may get up and be about.

Fig. 1058.—Fracture of the thigh. Convalescent ambulatory splint without traction.

Fig. 1059.—Fracture of the thigh. Convalescent ambulatory splint without traction. Coaptation splints may be applied to the thigh and held by straps enclosing the thigh.

The Standard of Results of Treatment of Fracture of the Femur.—Fractures of the femur seen early and treated by methods now available should recover with a correct alignment of the limb, full length of the limb, and functional usefulness of all joints. Shortening of the limb, instability of the knee, hyperextension of the knee, stiffness of the knee, backward bowing of the femur, permanent inversion or eversion of the foot, outward bowing of the femur, any angular deformity of the femur, limitation of movement at the hip or ankle, any of the defects above enumerated are not compatible with a perfect result following the treatment of a fracture of the shaft of the femur. It is possible to secure perfect results by the present available methods of treatment. This perfect result is the standard to be obtained.

Any departure from this standard result must be accounted for by the lack of skill of the surgeon, the delay in initiating treatment, the absence of adequate treatment, the complications of the case, compound fracture, crushing of soft parts, individual patient idiosyncrasies (of the reparative processes, non-union, unexplainable as yet), calamities.

Under ordinary conditions a closed fracture of the shaft of the femur should result in a functionally useful limb in a reasonable time (six months).

If we could get away from the general terms, "good," "fair," "poor," and "bad," commonly used in describing an end-result of an injury, and adopt in ordinary use more accurate terms it would be a desirable thing. It is, of course, impossible to set an absolutely exact standard by which to measure end-results.

The ultimate and highest aim of the treatment of a fracture is the restoration of the *function* of the part. The next factor in importance is the state of repair of the injured part—*its union*. The last factor is the appearance of the injured part—*its contour*. Perfect function, perfect union, perfect contour together mean a perfect result.

Moorehead arbitrarily expresses this in percentage figures. Function equals 60 per cent.; union equals 20 per cent.; contour equals 20 per cent.; total, therefore, 100 per cent. perfect.

In applying this method to a specific case it will appear as follows: if function is three-quarters perfect, $\frac{3}{4}$ of 60 = 45; if union is one-half perfect, $\frac{1}{2}$ of 20 = 10; if contour is one-fourth perfect, $\frac{1}{4}$ of 20 = 5. The result will then be 45 + 10 + 5, or a 60 per cent. result (Moorehead). A desirable method in industrial cases especially.

What shall be considered a satisfactory result in the treatment of a closed fracture of the shaft of the femur? It is always necessary to observe frequently and over a long period a fracture of the femur following firm union. It is surprising to find how often an apparently solid union will yield to body weight. Such yielding will at first not be noticeable to the patient, hence the importance of occasional observations by the skilled eye of the surgeon. Callus that yields to body weight may be made to yield to traction, pressure and bending of the bone both slowly and suddenly applied. How long after a bony fracture has bowed it may be affected by traction is experimental for each case of this kind coming under observation. Fractures of the femur that are thought to be pretty rigid will yield surprisingly easily under traction and pressure. Cutler has recently emphasized the "malleability" of bony callus. The degree of restoration of function cannot be determined with accuracy until about one year or less has elapsed after treatment is suspended.

The following six requisites for a satisfactory result following fracture of the femur are those reported by a committee from the American Surgical Association, and generally accepted as forming a good working basis: For a result to rank as a good one it must be established that firm bony union exists; that the long axis of the lower fragment is either directly continuous with that of the upper fragment or is on nearly parallel lines, thus

preventing angular deformity; that the anterior surface of the lower fragment maintains nearly its normal relation to the plane of the upper fragment, thus preventing undue deviation of the foot from its normal position; that the length of the limb is exactly equal to its fellow or that the amount of shortening falls within the limits found to exist in 90 per cent. of healthy limbs, namely, from $\frac{1}{8}$ to 1 inch; that lameness, if present, is not due to more than 1 inch of shortening; that the conditions attending the treatment prevent other results from those obtained.

A. **The Results of the Non-operative Treatment of Fracture of the Shaft of the Femur.**—From the clinic of Campbell and Speed, Memphis, Tennessee:

Treatment (p. 550) by anesthesia, traction, manipulation, immobilization. Cases of adults, 54 in all. Recent (within three weeks) fractures.

By *perfect result* is meant solid union, end-to-end apposition, no angulation, no shortening, perfect function.

By *good result* is meant solid union, less than 1 inch shortening, slight angulation. Satisfactory function.

By *poor result* is meant non-union, bony deformity, shortening 1 inch or more, bad angulation.

Results in these 54 cases were as follows: 60 per cent. perfect, 35 per cent. good, 3 per cent. poor; that is, 95 per cent. good results.

From this same clinic there were 57 acute cases in children, that is, fifteen years and under, giving 87.7 perfect results, 10.5 good results, 1.8 poor results, or 98.2 per cent. good results. Open reduction was done in but 1 case of delayed union.

B. **The Results of Non-operative Treatment of Fracture of the Shaft of the Femur.**—From the clinic of Conwell, Fairfield, Alabama: 110 acute cases, 80 per cent., were treated by skeletal traction, by caliper and Thomas suspension splint, and Pearson knee attachment; 20 per cent. were in children treated by adhesive plaster traction and Thomas splint.

Fifty per cent. had severe contusion of the soft structures; 9 had involvement of the knee-joint.

Nineteen were compound and comminuted, 91 were simple. In the compound fractures a thorough débridement was done in each case. A closure of the wound was made and antitetanic serum administered. Otherwise the treatment was similar to that in the simple fractures.

Open reduction was done in 4 cases; in 2 cases for interposed muscle tissue, in 2 cases because of delayed union.

The results in these adult laborers were as follows: Sixty-seven per cent. of these cases did the heaviest kind of work and 90 per cent. of these returned to the same work as before the injury. The average time for return to work for light duty was from four and a half to five and a half months. The average time lost from full duty was six and a half to seven months.

The results from Campbell's Clinic illustrate the fact that immediate reduction under an anesthetic and immobilization in a plaster-of-Paris splint yield a splendid percentage of good results.

The results from Conwell's Clinic illustrate the fact that immediate and

gradual reduction by skeletal traction yield a splendid percentage of good results.

Early mobilization of joints and massage should be practised with due regard to the complete reduction and the secure union of the fracture. The results from these two clinics may be taken as illustrative of the maximum to be expected today from the non-operative treatment. The results are brilliant, stimulating, and should lend renewed effort to the carrying out of non-operative treatment in appropriate cases.

Fracture of the Femur in Childhood.—There is no thought more fundamentally important to a consideration of the treatment of fractures of the femur in childhood than that expressed by Ashhurst when he says surgeons often make a mistake in very young children in regarding bones as things separate from soft parts; the bones were originally formed out of soft parts and the younger the patient the more intimate is the physiological connection between the two. The bones depend for their form on the action of the muscles and in the daily use of the limb; almost any deformity of the shaft of a long bone in a young child will be spontaneously corrected within six months or a year.

The alignment of the fragments of a fracture of the femoral shaft in the growing child is more important than the position of the fragments.

The younger the growing patient, the more readily and completely is there compensation for the malposition of the fragments of a fracture.

Fracture of the femur in childhood is usually caused by direct violence, very often an automobile injury, at times by a fall.

The transverse, oblique, and spiral types of fracture appear. The oblique and spiral are the most common. A supracondylar fracture is a bit unusual. The middle of the femur is most often broken.

Displacement of Fragments.—This is, of course, variable, but is less likely to be typical of adult fractures than one would suppose. In fractures of the upper third the upper fragment is displaced internally and posteriorly quite as frequently as in the orthodox adult directions (Burdick).

Occasionally the fracture will be incomplete, subperiosteal or greenstick. I have seen several greenstick fractures which have been supracondylar and in the middle of the shaft.

The *principles of treatment* to be kept distinctly in mind in this very special group of injuries:

A. The most simple form of treatment is best.

B. The initial treatment should be the permanent treatment when possible.

C. Perfect anatomical reduction is not essential for perfect functional recovery.

D. Displacement and overriding of fragments will result in a good functioning limb, without tilting of the pelvis or compensatory spinal curvature or appreciable deformity.

E. Shortening of the limb is usually compensated for by growth in length of the fractured bone.

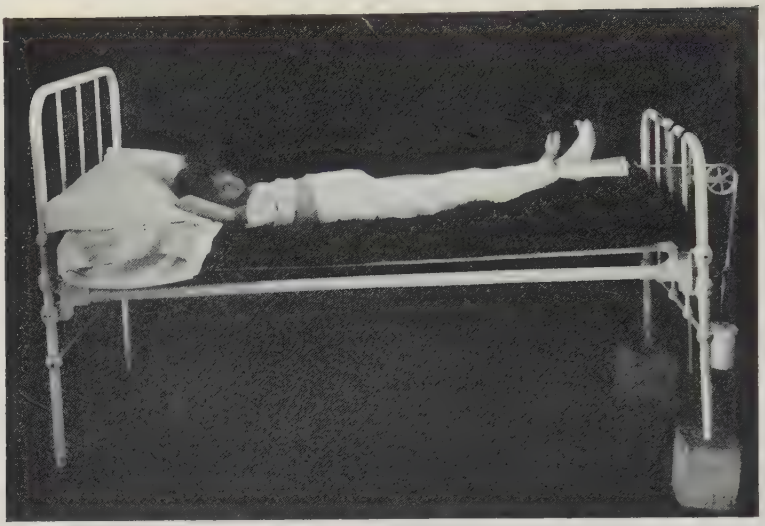


Fig. 1060.—Fracture of the shaft of the femur in a child over six years old, treated by plaster-of-Paris spica and traction. Note spica splint traction, countertraction by elevation of the foot of the bed (Burdick and Siris).

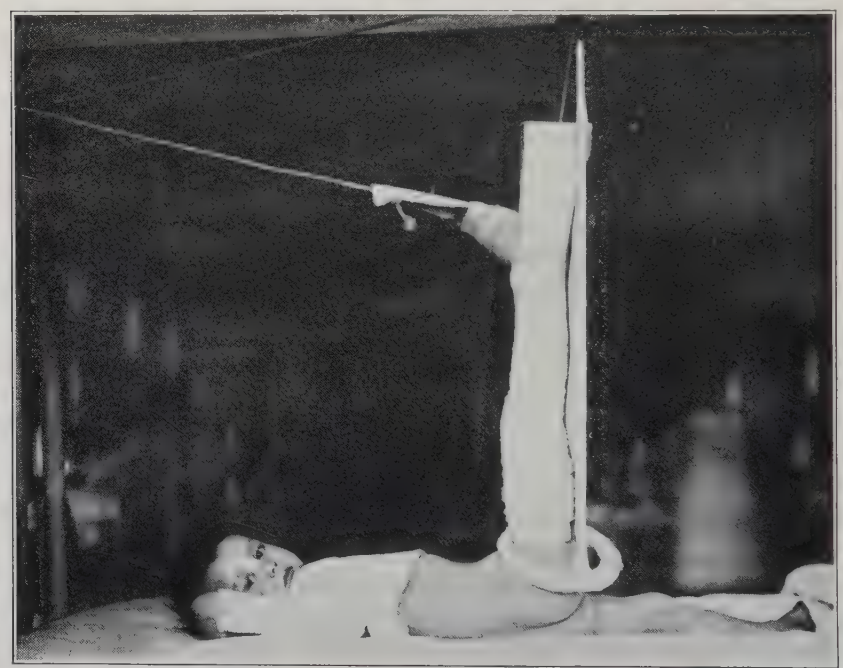


Fig. 1061.—Fracture of femur. Overhead extension. Buck's extension raises the buttocks, on the injured side, off the mattress (David, Archives of Surgery, September, 1924).

Immediate Treatment.—These small patients stand shock poorly. Every care, therefore, bestowed on them will be positively beneficial. They react kindly to treatment.

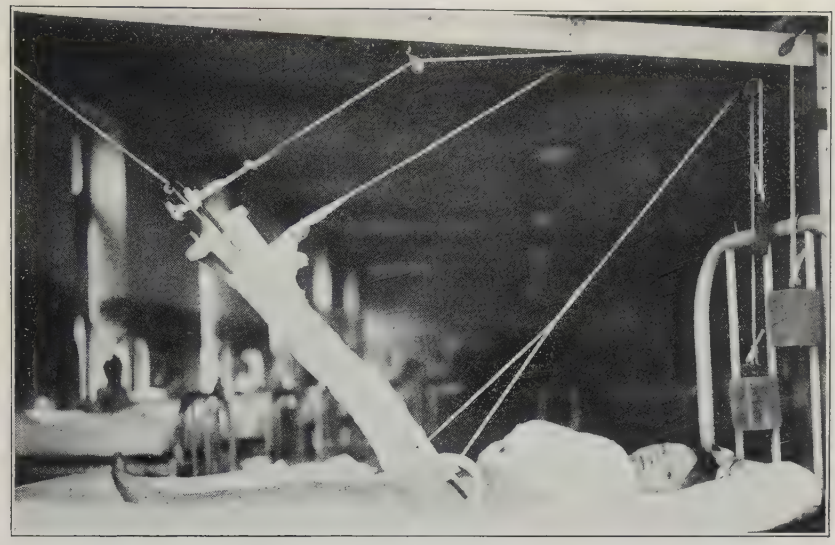


Fig. 1062.—Fracture of the shaft of the femur (older child). Lower extremity held in abduction and external rotation. The cord of the extension taken a turn around the end of the Thomas splint, so that the traction is through the splint and is more uniformly distributed to the traction apparatus on the leg (David, Archives of Surgery, September, 1924).

Fig. 1063.—Thomas caliper walking splint (David).

On admission to the hospital or to the home after the accident the facts regarding the injury and the nature of the fracture are always determined with the help of the fluoroscope. The deformity, the presence of shortening, and the position of the limbs are recorded.

A towel loop is placed about the ankle of the injured limb, a rope is attached so that immediate traction over the end of the stretcher or receiving

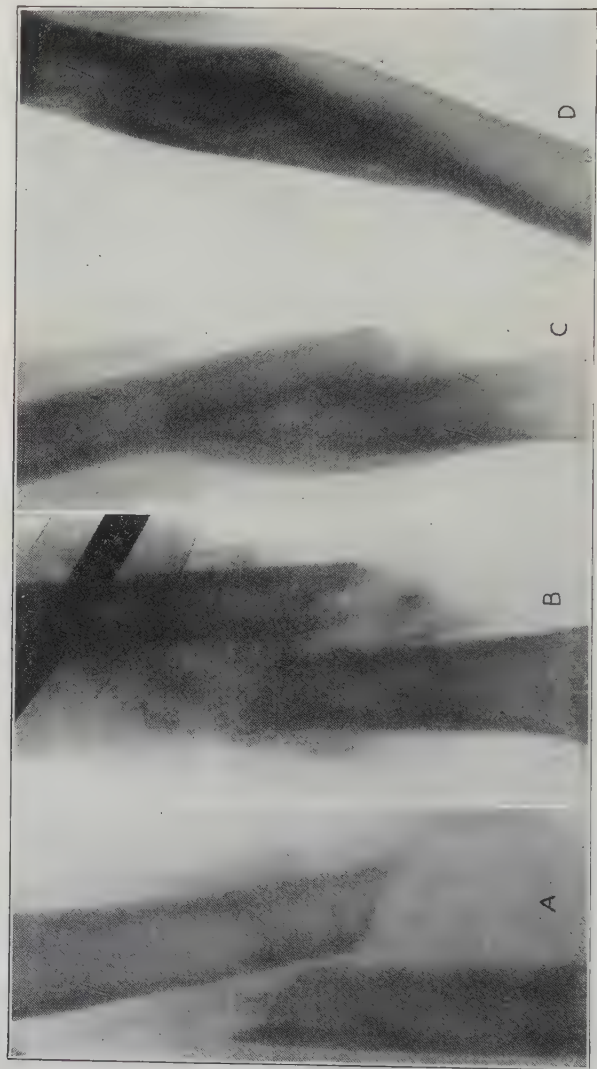


Fig. 1064.—(Case 1, G. F., aged eight years.) A, Femur in extension two days after injury; 1 inch shortening; no end-to-end apposition of fragments. B, Appearance three weeks after injury, with callous formation; ⅞ inch shortening and good alignment. C, Appearance three months after injury. The walking caliper has been removed and there is ½ inch shortening. D, Thirteen and one-half months after injury. No shortening and no apparent deformity. (David, Archives of Surgery, September, 1924.)

bed may be made. Eight to 16 pounds traction will immediately relieve the patient of pain, overcome muscle spasm, prevent further shortening, and greatly facilitate subsequent reposition of fragments.

So important is this immediate corrective emergency treatment that its employment cannot be too insistently and emphatically demanded.

All fractures should be treated at the hospital and in private practice as the most important kind of an emergency. Fractures of the thigh especially (the femur being the big bone of the child's body) should be regarded as important emergencies.

The patient is immediately (unless some special contraindication exists) anesthetized. If the fracture is transverse, a successful locking of the fragments may be brought about by manipulation.

An adhesive plaster moleskin extension is applied from the top of the thigh *above* the level of the fracture to the ankle. The whole tube of soft parts—skin, muscles, fasciæ, and the lower fragment—will be pulled most effectively by thus enveloping the whole limb (Hey-Groves).

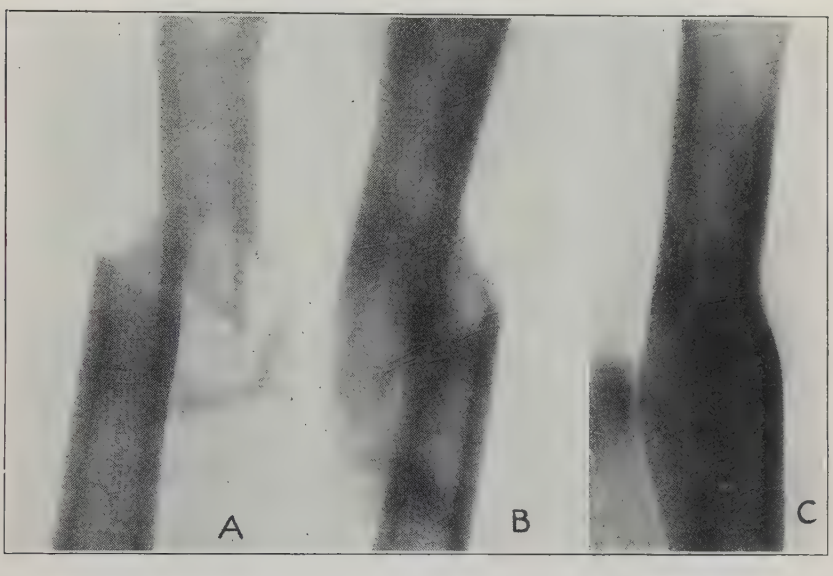


Fig. 1065.—(Case 2, A. G., aged eight years.) A, Transverse fracture of the upper third of the femur eight days after injury. There is little shortening. B, Appearance nine weeks after injury. The femur is in a walking caliper. There is some overriding, with $\frac{1}{2}$ inch shortening. C, Appearance five months after injury. There is no shortening and no apparent deformity.

The *permanent dressing* and the exact handling of the limb will depend on the age of the child, the size of the limb, as well as on the kind of fracture.

Ordinarily, if a greenstick fracture has been corrected under an anesthetic, an immediately applied plaster-of-Paris spica splint will prove satisfactory. In children of ten years or under the Cabot posterior wire frame with coaptation splints and extension is a very comfortable way of handling such cases (see Fig. 1070).

In small children under six or eight years the suspension in a Bryant overhead traction position will be simple and suitable (see Fig. 1073). If the fracture has been locked, completely reduced, or if there is little overriding, both limbs may be suspended, this being a comfortable position.

It has been observed that the pull with one limb suspended, just so the buttock clears the bed, is 25 to 33 per cent. greater than with both limbs suspended (Burdick and Siris).

The amount of abduction needed will vary, but should be at least 20 to 30 degrees.

After four weeks the suspension is omitted. The child is kept in bed for about two weeks longer without traction or splint.

Fig. 1066.—"Case 2." Appearance twenty months after injury. There is no shortening and practically no deformity (David, Archives of Surgery, September, 1924).

The experience of most surgeons, I believe, with the overhead traction is that it serves really only as a means of immobilization and not as an active method of extension and counterextension.

The adhesive plaster, like all adhesive plaster extensions, is liable to slip and cause excoriations of the skin and ulceration about the ankle and foot.

Bradford Frame with Vertical Suspension.—In very small children it is sometimes wise to use the Bradford frame (Fig. 1075) and vertical suspension (Fig. 1074) of one or both thighs. This is an efficient, comfortable, and clean method of treatment. The Bradford frame is an iron, frame-like stretcher on which the child lies and to which the shoulders and hips are

Fig. 1067.—"Case 6." Appearance eleven months after fracture, showing equal length of femora and lack of deformity (David, Archives of Surgery, September, 1924).

fastened to prevent the child's moving about. Counterextension is then secured by the immobilization of the pelvis and hip. The extension is applied to the thigh and leg as usual. The limb is flexed on the body to a right angle, coaptation splints being applied to the thigh. After the novelty of the position passes away the child is perfectly contented. As soon as union is firm the permanent plaster spica dressing may be applied, and the patient

may be up and about with high shoe upon the well foot and with crutches. The use of the long hip-splint will be of great service in these cases either with or without the extension foot-piece (see Figs. 1058, 1059). After fracture of the shaft of the femur in children there should be no shortening and

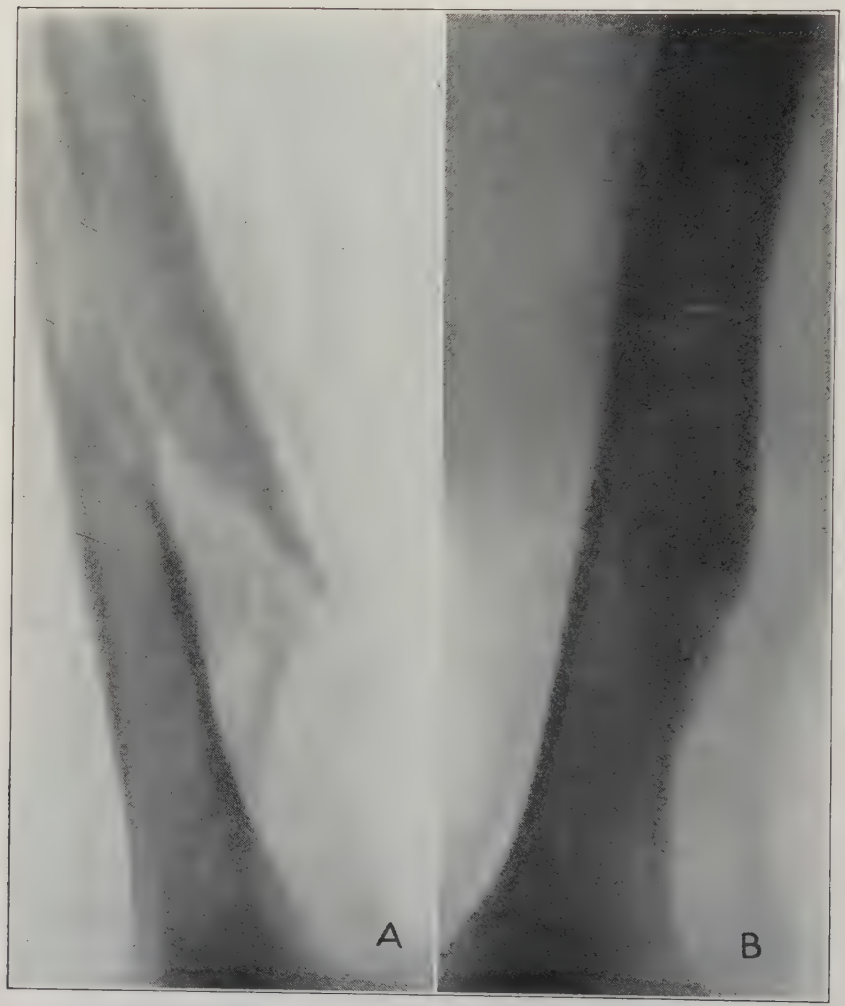


Fig. 1068.—"Case 6." W. R., aged four and a half years. A, Oblique fracture of the lower third of the femur after five weeks in overhead extension. There is ⅜ inch (9.5 mm.) shortening. B, Appearance five and a half months after injury. There is no shortening and no apparent deformity. (David, Archives of Surgery, September, 1924.)

no special difficulty in convalescence. It is wise to guard the thigh a sufficient time after union is firm to insure absolute solidity and freedom from bowing in any direction (Figs. 1063, 1077).

The Making of the Bradford Frame: It is most easily made from ⅝- to ¼-inch gas piping. It should be 1 inch wider than the width of the hips,

and 6 inches longer than the height of the child. It should be covered with canvas, so as to leave a space under the buttocks for the use of the bed-pan.

Fractures in Older Children.—Immediate reduction and fixation in a plaster-of-Paris spica with continuous traction is advocated. After reduction with the assistance of the Hawley table an adhesive plaster extension is applied, and then a plaster spica (Fig. 1060, Burdick). Some 10 or 15 pounds weight extension is used. The foot of the bed is elevated.

Roentgen rays are taken for a record of the situation. The extension is used rather to prevent loss of all that is gained at the time of the manipula-

Fig. 1069.—Boy four years old. Fracture of the shaft of the left femur. Two to three inches overriding of fragments. Patient on Bradford frame. Hips held by towel swathe to frame. Key-Schmerz ice-tongs applied. Buttocks just clear the bed. Note tongs and dressing about knee which is flexed at a right angle. Anterior bowing corrected by traction over dorsum of thigh by 2½ pound weight to pulley at foot of bed. Leg and foot held at a right angle. Caliper removed after three and a half weeks. Plaster-of-Paris splint (Thorndike).

tion and attempted reposition rather than to accomplish anything positively better in reduction.

The splint is removed after six weeks. There will be no limitation of motion at the hip, only temporary disability of the knee. The patient is out of bed in two more weeks, with the thigh protected from bending for two weeks more, moving about with crutches, and finally full weight bearing after all likelihood of bending of the callus is past (Burdick).

The *use of the Thomas splint* as in adults (p. 217) is valuable in cases of compound fracture, in cases requiring skeletal traction, in cases

which should not have a general anesthetic and must be gradually reduced by traction.

Overhead suspension, combined with the steadying help of the Thomas splint, is found advantageous in certain small children (see Fig. 1061, David).

Then, again, in children over eight years the overhead will be found uncomfortable. One may use in such cases a Thomas splint in considerable flexion of thigh on the body and maintaining correct alignment by sufficient abduction (Fig. 1062, David).

The Operative Treatment in Childhood.—The need for direct fixation of the shaft of a femur in children in recent fractures will rarely arise. In neglected fractures, in those with serious overriding of fragments, the ends should be freed and replaced and fixed. Internal non-absorbable fixation material should eventually be removed.

Skeletal Traction (p. 217).—In children when adhesive traction is ineffective, especially in older children, borderline children, muscular children, in fractures that have been untreated for some days, where a strong traction force is needed, skeletal traction will be found to be sane, safe, and satisfactory (Fig. 1069, Thorndike).

In the application of the caliper the synovial pouch and the epiphyseal line must be avoided. The caliper should be applied in the shaft of the femur well above the epiphyseal line, higher than is customary in the adult.

The careful use of the caliper skeletal traction will very materially lessen the number of operative fractures in childhood. Many fractures in children are unnecessarily operated on.

The Results of Fracture of the Femur in Childhood.—Usually a perfect result is eventually obtained, without shortening, deformity, joint stiffness, and with perfect function.

I wish to present the evidence carefully collected by Burdick, Cole, David, and others, that overlapping of fracture fragments of the femur, displacements of such fragments, are eventually completely compensated for by the natural growth of the child.

These facts should not make us less careful, but more careful of our treatment of these cases. These facts will prevent unwise operations on the bones of children.

When confronted with a fracture of the shaft of the femur in a child over ten years old, which is difficult to reduce, even granting that perfect reduction is unnecessary because of the compensating action of growth, the question will occasionally arise, is it good judgment to allow this child to recover from this immediate injury with shortening and lack of perfect alignment? Is it wise to take the attitude that this child can afford to wait one year, two years, or even three years before a functionally normal limb is obtained? How far shall we allow this natural compensatory effort of growth to influence the choice between operative and non-operative treatment? If immediate operation is done ideally, the result will be immediate in normal time—six months or so.

I believe that there will be occasional cases in which operation will be wise. I believe there will be occasional cases to which the caliper traction will be applicable. I believe that most cases should be treated by non-operative traction methods.

The Cabot Posterior Wire Splint (Fig. 1070).—The splint consists of two portions—a body part and a leg part. The patient lies upon the body part with the thigh and leg resting upon the leg part, as upon a coaptation splint. Having a vise and simple iron wire the size of an ordinary lead pencil, this splint can be made in a few moments; the bending of the wire according to the diagram and fastening the free ends by a strip of small-sized wire being all that are required. It is necessary to make the following measurements before bending the wire to the general shape shown in the diagram, namely, D–E, the distance from the axilla to the calf of the leg; A–D, the width of the trunk; A–B, from the axilla to a point midway between the crest of the ilium and the top of the great trochanter; F–E, the width of the leg, usually from 2 to $2\frac{1}{2}$ inches. A–D and B–C are bent to the curve of the back. B–C is so bent that it jumps over the sacrum and does not touch posteriorly excepting at B and C. The long rods are so bent as to adapt them to the posterior curves of the buttock, thigh, popliteal space, and leg (Fig. 1071). The splint is covered, as in the posterior wire splint for the leg, by layers of sheet wadding and cotton bandages. A swathe is attached to the two sides A–B and D–H of the body part (Figs. 1070, 1072). The child is carefully laid upon this splint, the body swathes adjusted, the extension strips applied, traction made by weight and

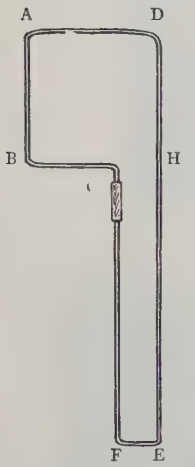


Fig. 1070.—Cabot wire splint for fracture of the hip and thigh.

Fig. 1071.—The Cabot wire splint ready for use. Lateral view, showing curves of splint corresponding to small of back, buttock, and knee.

pulley with the foot of the bed elevated, coaptation splints applied and held in position by straps that include the posterior wire splint. If it is necessary to move the child for the making of the bed, for the use of the bed-pan, or for bathing, the extension may be unfastened temporarily without any injury to the fracture, particularly if the coaptation splints are then temporarily tightened to secure a firmer hold on the thigh. The child should be, of course, clean from both urine and feces, and the fracture immobilized.

After four weeks of bed-treatment the child may be up, with crutches and a high shoe with the Cabot splint applied. Shoulder-straps should be attached to the splint when it is worn in the erect position. This is one

of the simplest, cleanest, and most efficient methods of treating fracture of the thigh in young children. The child can be moved with freedom and

Fig. 1072.—The Cabot wire splint ready for use. Front view, showing covering of Canton flannel and Canton flannel double swathe for fixation to chest.

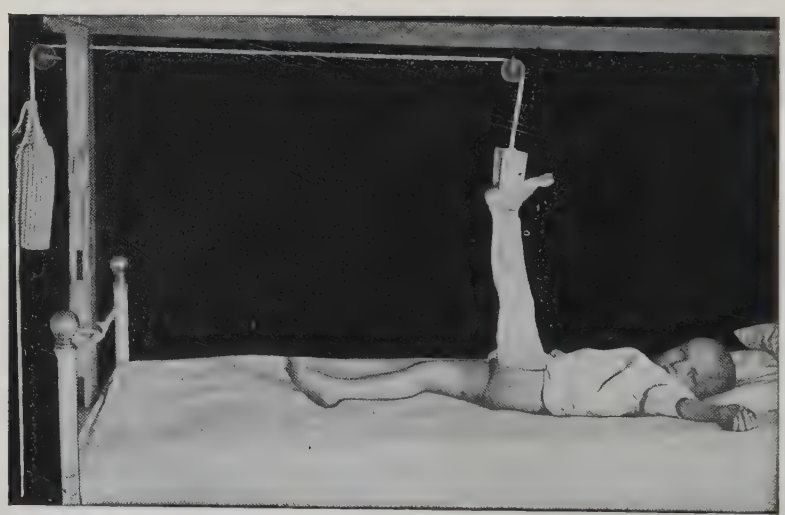


Fig. 1073.—Method of suspending lower limb in fracture of the thigh in a child. Note extension strips held by a bandage from groin to ankle, spreader, cord, pulleys, weight, and post for holding pulley (Davison). See Fig. 1074 for complete dressing.

without pain. A light plaster-of-Paris spica bandage may be used in convalescence with crutches and a high shoe on the uninjured side.

Fig. 1074.—Fracture of the femur in a child. Note Bradford frame on which child rests, the position of the lower extremity. Shoulders and trunk of child held fixed by straps and swathe. Note coaptation splints, extension, weight, and pulley. A comfortable position for child. An efficient method of treatment.

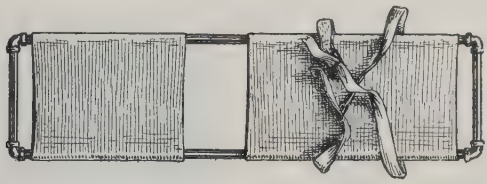


Fig. 1075.—Bradford bed-frame for fixation of trunk in fracture of the thigh.

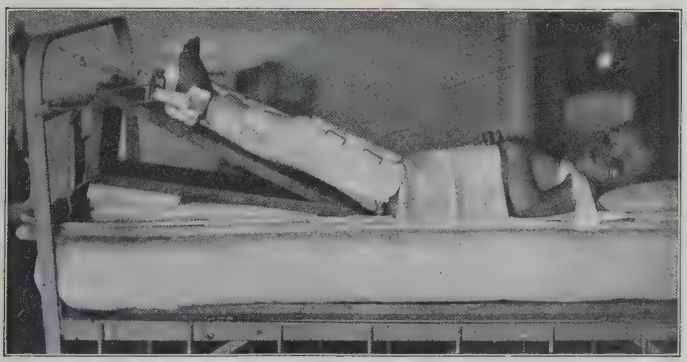


Fig. 1076.—Fracture of the thigh in a child. Vertical suspension as in Fig. 1074 has been followed. After two weeks the lower extremity is lowered to this position upon an inclined plane before completely lowering to bed level. Inclined plane made of three pieces of rather heavy wood for solidity. Note the extension in the line of the long axis of the lower extremity (Davison).

Fig. 1077.—Old fracture of the femur with deformity. Due to use of unprotected thigh before complete consolidation of the fracture (Warren).

Fig. 1078.—A seven-year-old boy, run over, circulation poor, leg cold and pale. Two attempts at reduction failed. Double inclined plane. Circulation improved. Toe-drop. Three months after accident impossible to reduce epiphyseal separation. Resection of joint done. Toe-drop persisted. Poor result. Shortening (Binney and Lund).

Fig. 1079.—An eight-year-old boy. Compound separation. Toe-drop. Six years after the accident 2 inches shortening. See Fig. 1080, lateral curvature present (Binney and Lund).

Fig. 1080.—Same case as Fig. 1079. Note lateral curvature and lack of growth of the left lower extremity six years after injury to lower femoral epiphysis (Binney and Lund).

SEPARATION OF THE LOWER EPIPHYSIS OF THE FEMUR

Anatomy.—The lower epiphysis of the femur is the largest of the epiphyses. It unites with the shaft of the bone at or about the twenty-first

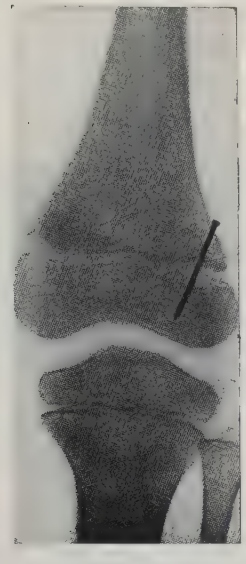


Fig. 1081.

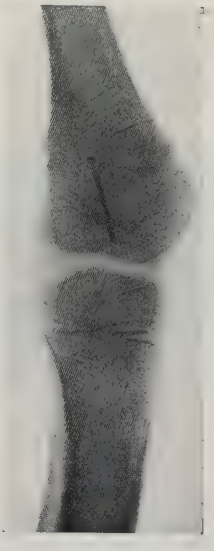


Fig. 1082.

Figs. 1081, 1082.—Compound separation of lower epiphysis of femur. After cleansing and fixation by a nail immobilized by a plaster dressing in slight flexion. Nail removed after seven weeks (Binney and Lund).

year. The epiphysis includes the whole of the articular surface of the lower end of the femur. The points of origin of the gastrocnemii muscles are

Fig 1083.—Partial recurrence of displacement after two trials at replacement. Difficult to hold (Binney and Lund).

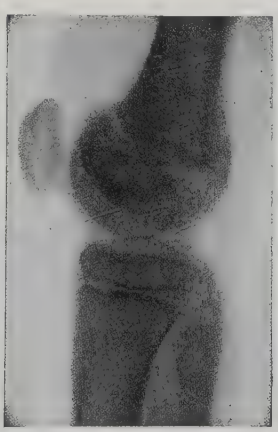


Fig. 1084.—Two recurrences of displacement. Held finally by acute flexion of knee (Binney and Lund).

situated upon the epiphysis; a few fibers only arise from the diaphysis. The inner condylar line of the femur is continuous with the inner lip of the

linea aspera, and terminates at the adductor tubercle, which can be palpated upon the inner side of the thigh near the knee-joint. The upper and outer angle of the trochlear surface of the femur can be palpated best with the knee flexed. A line drawn from this angle of the trochlea to the adductor tubercle marks the level of the lower epiphysis of the femur. In no position of the knee-joint are the bones in more than partial contact. This is one of the superficial joints of the body. The strength of the joint lies in the ligaments and fasciæ about it. Unlike the elbow- and hip-joints, it

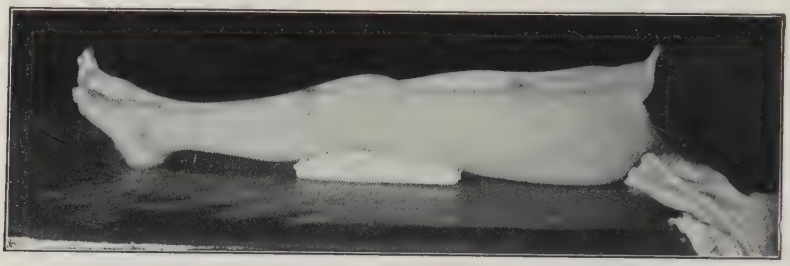


Fig. 1085.—Boy eleven years of age. Separation of the lower femoral epiphysis. Photograph taken four hours after the injury. Note inversion of the limb; fulness of lower third of thigh posteriorly; fulness over head of tibia; fulness in popliteal space (*x*-ray tracing, Fig. 1087, explains the evident deformity).

does not depend upon the contour of the bones for strength. An attempt to overextend and to bend the knee laterally brings very great strain to bear upon the ligaments that are attached to the lower femoral epiphysis. If this strain is of sufficient force, the epiphyseal cartilage gives way, and the epiphysis separates from the shaft of the femur. The common cause of the accident is the catching of the leg or thigh in the spokes of a revolving wheel. The accident most often occurs to boys about ten years old (Figs. 1085, 1086).

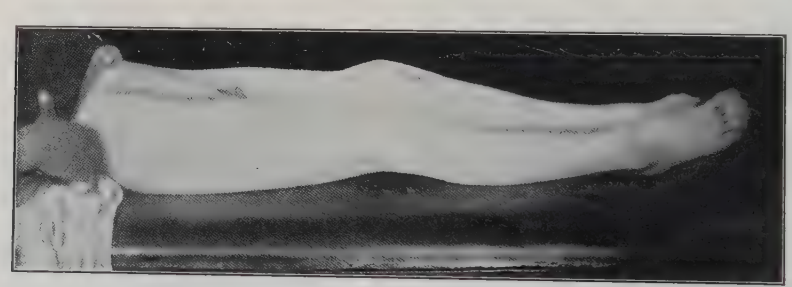


Fig. 1086.—Same as Fig. 1085. Separation of the lower femoral epiphysis of the left leg. Contrast two knees (see *x*-ray tracing, Fig. 1087).

The epiphysis usually separates without splintering the diaphysis. The periosteum is stripped for a considerable distance. About half the cases are open, the end of the diaphysis projecting through the skin of the popliteal space. The knee-joint is usually unopened. There may be almost no displacement of the fragments. A lateral sliding of the epiphysis has often been observed. One condyle has been found in the popliteal space, but commonly the epiphysis lies in front of the shaft of the femur with its sepa-

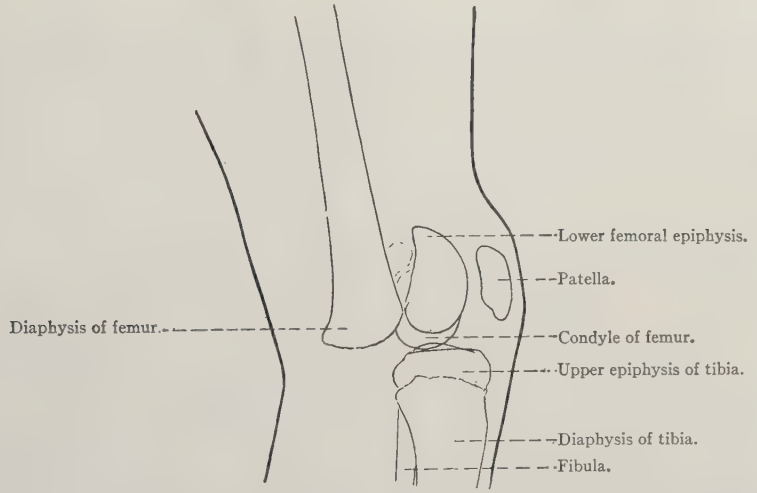


Fig. 1087.—Lateral view. Case of Fig. 1085. Boy aged eleven years. Separation of the lower femoral epiphysis. Displacement forward of epiphysis and backward of lower end of shaft (see Figs. 1085, 1086, *x*-ray tracing).

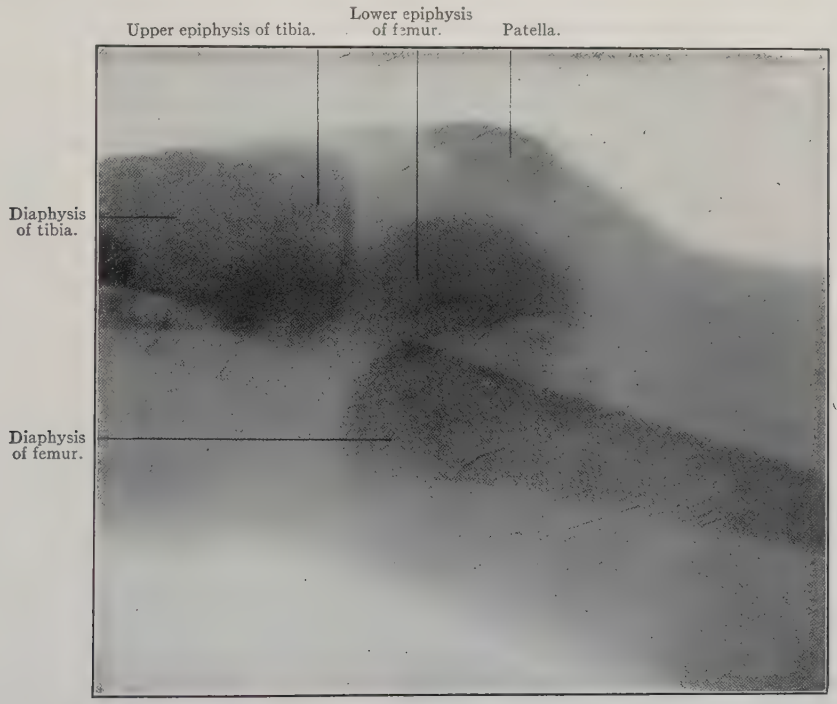


Fig. 1088.—Separation of the lower femoral epiphysis in a boy aged eleven years, taken before operation. Open incision, reduction, recovery with a useful knee.

rated surface in contact with the shaft (Figs. 1078, 1087, 1091). The diaphysis is displaced backward and downward into the popliteal space, because the high attachment of the gastrocnemii has not been stripped off the shaft.

The fracturing force is the most important factor in determining the displacement of the lower end of the upper fragment. The nerves of this region may be pressed upon or lacerated, and this may be the cause of great pain

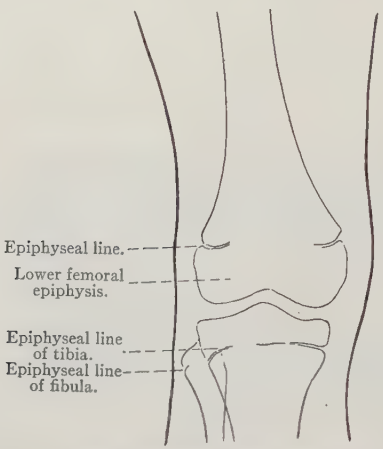


Fig. 1089.—Same case as Fig. 1087. Anteroposterior view of uninjured knee in a child eleven years of age, showing epiphysis in position (*x*-ray tracing).

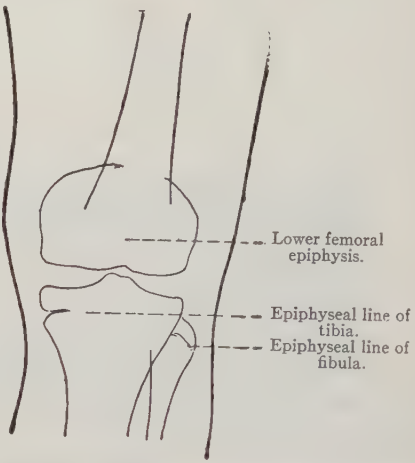


Fig. 1090.—Same case as Fig. 1087. Anteroposterior view of d splaced lower femoral epiphysis in a boy eleven years old.

attending the accident. The popliteal vessels may be compressed, stretched, or even ruptured. Consequently, interference with the circulation may result. This may be moderate and temporary, or extreme, and result in

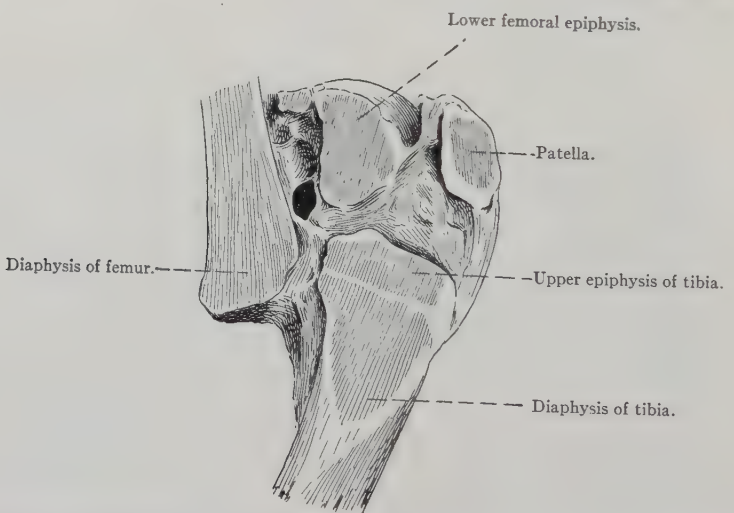


Fig. 1091.—Separation of lower epiphysis of the femur with displacement forward and upward between femoral diaphysis and patella (Warren Museum, 8116–1, Cotton).

gangrene of the leg. The shock attending this accident is often great. Suppuration may appear in closed separations, although it is infrequent; it is much more likely to appear in open lesions. Sloughing of the skin is not

unusual from the bony pressure. Gangrene of the leg sometimes occurs. Necrosis of bone is not unlikely to result, particularly if the separation of the periosteum is great (Fig. 1091).

One case is recorded of pulmonary embolism resulting from thrombosis of the popliteal vein. The nerve most seriously injured is the external popliteal. Slight toe-drop is the sign of such injury.

Diagnosis.—After severe trauma to the region of the knee in childhood there are three injuries that should be considered possible: a dislocation of the knee-joint, a supracondylar fracture of the femur, or a separation of the lower epiphysis of the femur.

There may be so much swelling that a satisfactory examination is impossible. Ordinarily, careful palpation will detect the bony outlines of a dislocation. An *x*-ray will always reveal the injury and should be used whenever practicable. This is extremely rare in children. The crepitus of a supracondylar fracture is bony and hard, and the displacement of the distal fragment into the popliteal space evident. All fractures at the knee are not necessarily supracondylar. Several cases of fracture of one condyle of the femur into the joint are reported. The separated epiphysis itself may be split through into the joint. A severe trauma to the knee, a cartwheel accident to a young boy, attended by considerable shock, followed by great swelling of the knee, a marked prominence of the patella together with a transverse depression above the patella across the thigh, a fulness in the popliteal space, feeble or absent pulsation in the dorsalis pedis and posterior tibial arteries, increased lateral and anteroposterior mobility at the knee, and soft crepitus form the picture characteristic of a separation of the lower femoral epiphysis.

Prognosis.—It is impossible to state positively that in any given case there will or will not be shortening of the leg upon the injured side because of a cessation of growth in the femoral epiphysis. If the epiphysis is separated without great laceration and periosteal denudation and is replaced soon after the injury, the chances are that there will be a minimum amount of shortening of the affected leg. There is recorded one case of a boy seven years old, separation of lower femoral epiphysis, replaced eight weeks later by incision, whose legs two years afterward were of exactly the same length. This case demonstrates that separation of this epiphysis, even after reduction eight weeks subsequently, does not interfere with the growth of the bone. After open incision and replacing of the epiphysis in closed fractures good results are to be expected as far as the usefulness of the joint is concerned. Slight necrosis of bone may attend convalescence, but is most unusual. If the separation is closed and reduction is impossible by manipulation alone, open incision should be made.

Treatment.—If the vessels are torn, if there is great laceration of the soft parts, amputation should be performed. If the separation is open and the shaft of the femur protrudes through the wound, and much of the diaphysis is seen to be denuded of periosteum, the diaphysis and all the soft parts should be thoroughly cleansed and the bone reduced. It may be neces-

sary to enlarge the opening in the soft parts before it is possible to reduce the bone. If the separation is closed, reduction by manipulation should be attempted; if successful, the leg should be flexed to a right angle or an acute angle and immobilized in a plaster-of-Paris splint.

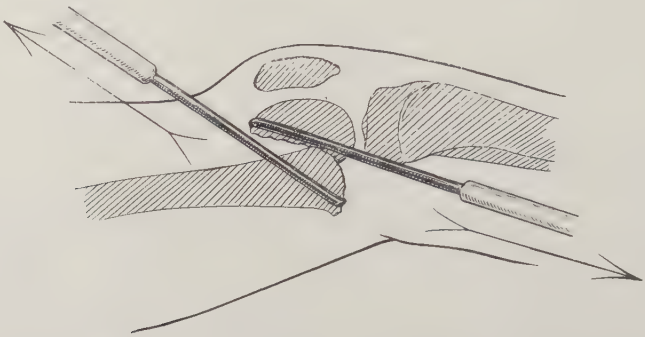


Fig. 1092.—Diagram to show method of reduction of separated femoral epiphysis by incision. Retractors are upon diaphysis and epiphysis, and lines of traction are shown by arrows.

The pressure downward is upon the edge of the displaced epiphysis at the point indicated by the line pointing to the "lower femoral epiphysis" in the figure.

Reduction by Manipulation When the Fragment is Displaced Forward.—While an assistant makes traction upon the leg, the surgeon, grasping the thigh above the condyles with the fingers in the popliteal space, making pressure on the upper fragment, pushes with his two thumbs upon the upper border of the displaced epiphysis (see Fig. 1089). The pressure downward is upon the edge of the displaced epiphysis at the point indicated by the line pointing to the "lower femoral epiphysis" in the figure. The leg is gradually flexed. If the reduction is achieved, a soft grating sensation will

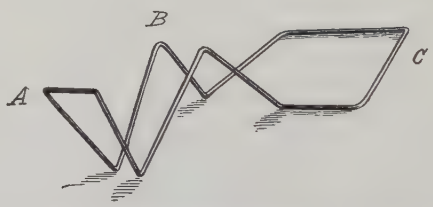


Fig. 1093.—Cabot splint arranged as double inclined plane for epiphyseal separation at the lower end of femur. *B*, The part behind the knee-joint, may be bent to a more acute angle; *C*, the body portion, is to be molded to the trunk; *A*, the foot-piece. With the angle at *B* obliterated the splint may be used for fracture of the leg in childhood (see Figs. 1071, 1072).

have been felt, and the shortening of the leg that existed previous to reduction will disappear. The contour of the knee will assume a somewhat normal appearance. After reposition of the displaced epiphysis the leg and thigh are immobilized so that the heel is close to the buttock. This forced flexion uses the tightened quadriceps and relaxed hamstring muscles as a properly balanced retaining splint.

It has been found possible to avoid operative reduction, when ordinary manipulation failed, by arranging a canvas strap over the displaced fragment (epiphysis) so that the force can be increased beyond that obtainable by manual and digital pressure. A canvas loop passing over the epiphyseal fragment and to the floor where it is held by the surgeon's foot will focus pressure often advantageously, so as to effect reduction.

Reduction has also been aided by manual traction on folded towels arranged as the straps described (Wier).

The Operative Method of Reduction.—The obstacle to reduction is no single band or obstruction, it is the retraction and tension maintained by

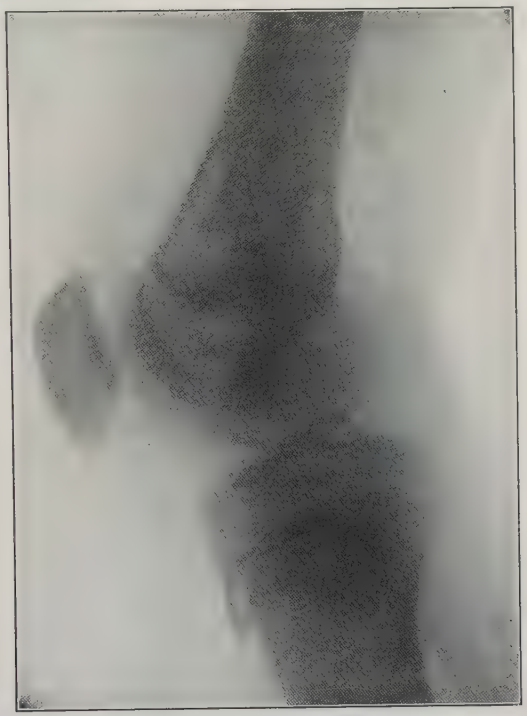


Fig. 1094.—Separation of the lower femoral epiphysis in a boy fourteen years old. Reduction without operation. Recovery. This *x*-ray was taken after recovery. Before operation the *x*-ray was similar to that shown in Frontispiece "C." Functionally slight loss of extension.

the fasciæ, ligaments, and muscles of the thigh upon the tibia. This retraction is so great that the tibia is held crowded against the lower end of the upper fragment, and prevents the replacing of the epiphysis. An incision is best made over the denuded shaft of the femur on the outer side of the leg. The shaft and the epiphysis are exposed in the wound. Traction should be made by means of periosteal retractors upon the epiphysis, and countertraction upon the diaphysis while the leg is slowly flexed from the completely extended position, as indicated (Fig. 1092). This will result in the reduction of the displacement. Suture of the bones may be needed

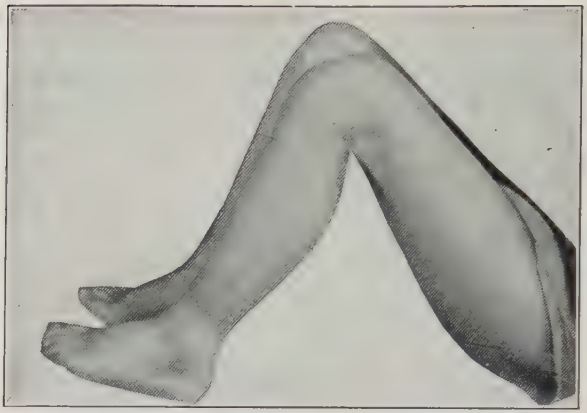


Fig. 1095.—Boy aged eleven years. Separation of left lower femoral epiphysis; incision, reduction. Recovery. After six months, useful leg. Knee motion in flexion beyond a right angle as shown (see Figs. 1081–1091 inclusive).

Fig. 1096.—Case same as that in Fig. 1095. Separation of lower femoral epiphysis. Note degree of extension possible and cicatrix of incision six months after operation. Note also absence of deformity.

to retain the replaced epiphysis in position. A steel nail may be used and left in permanently or removed after union is firm. The flexed position of the leg will assist materially in retaining the fragment in position. The

application of a light-weight plaster-of-Paris circular bandage from the toes to the groin, with the leg flexed to a right angle, will immobilize the parts.

After Union is Firm Between the Epiphysis and Shaft: After three or four weeks the leg may be gradually extended. The foot of the injured leg may be touched to the floor while the plaster splint is in place about five weeks after the injury. Slight weight may be borne upon it. The plaster should be removed after about six weeks, and gentle active and passive motion made at the knee-joint. Massage to the calf of the leg and the thigh should be given daily. A flannel bandage applied to the foot, ankle, leg, and thigh will be all the support that is needed. After about ten weeks the boy should be allowed to step on the foot all he chooses. At first he will do this with fear, but soon with confidence. There may be a little limitation of motion in the knee-joint finally (Figs. 1095, 1096).

Repeated x-Rays Necessary.—There is a great tendency for this displacement of the epiphysis to recur wholly or partially after it has been thoroughly reduced. Therefore very careful *x*-ray supervision is necessary until sufficient time has elapsed to ensure firm union. Accurate reduction is important because of the danger of limited flexion and faulty growth following this injury.

GAS GANGRENE

Occasionally gas gangrene in civil life develops in crushing compound fractures. These injuries furnish osteomuscular wounds which afford suitable conditions and media in the devitalized tissues for the development of anaërobic and aërobic bacteria. Gas gangrene is caused by the "Vibrion septique" or Welch bacillus, an anaërobic bacillus, which develops in the compound wound within twelve hours of the accident.

Pilcher has recognized three stages in the progress of symptoms:

First stage limited to the first twelve hours. There are no visible signs. There is a characteristic odor noticeable about the wound before gas has formed, a slight swelling of the wound, and a sick patient.

The *second stage* appears as soon as gas forms in the superficial tissues. There is local muscle gangrene. If a tourniquet is used, causing interference with the blood-supply, the progress of the gangrene will be especially rapid.

Gas will form speedily. There will be local edema from the toxic products. The accumulation of gas and fluid will cause an anemia of the parts from pressure, the skin will become tense and white, and the third stage of massive gangrene will be ushered in.

The Third Stage.—A general toxemia will exist due to the absorption of soluble chemical substances without blood invasion by the organism. The skin will assume a dirty grayish-green color, subcutaneous crepitation will be elicited on palpation, blebs containing a serosanguinolent exudate will appear over the part. The distal pulse of the extremity has disappeared. A massive gangrene of the part will exist. The treatment should be the prompt and energetic use of perfringens antitoxin at any stage of the disease. This antitoxin may be secured from the Lederle Antitoxin Laboratories, 511 Fifth

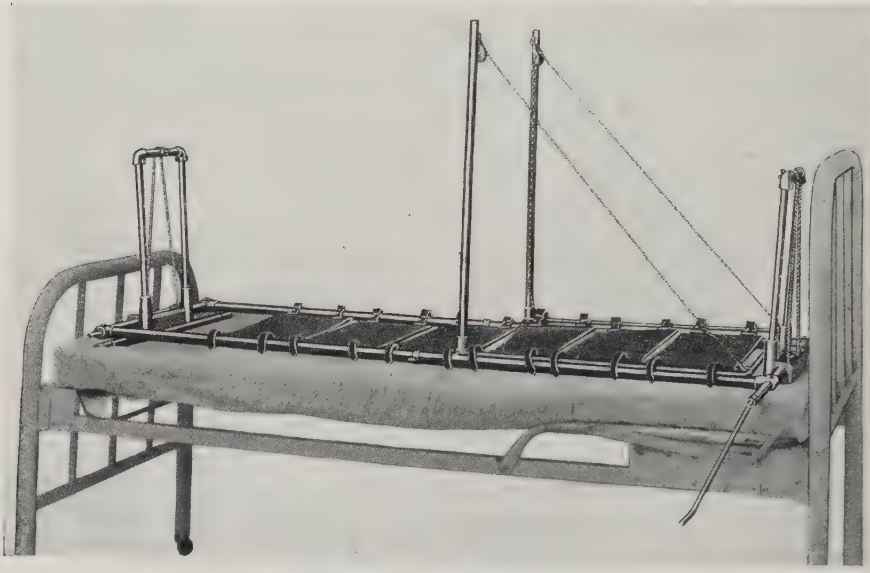


Fig. 1097.—Langworthy's portable elevator frame for bedfast patients and fracture patients. It is used on an ordinary hospital bed or home bed. Patient lies on canvas slings, which support him from head to feet when frame is elevated. If the softness of a mattress is desired, slings are kept slack. If a hard, firm bed is desired, the slings are tightened. Details shown in further pictures bring out usefulness of frame in cases where routine care of patient needs to be conducted without moving patient, or where the conditions make lifting patient difficult and painful (Langworthy).

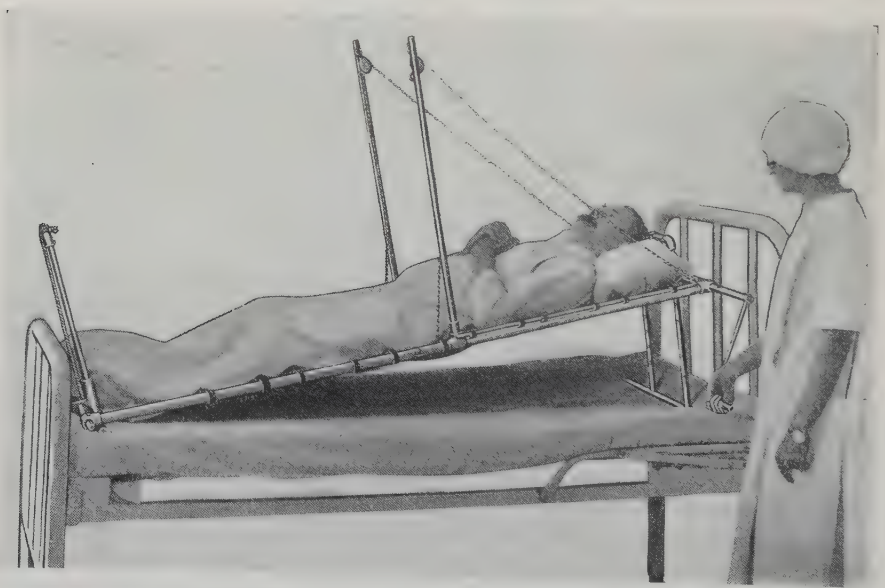


Fig. 1098.—Nurse elevating patient on frame. Head end of frame is raised by turning crank. The foot end is then raised in the same way. Patient thus elevated can be sustained in level position 15 inches above the bed, or at any lower level, or with head higher, or feet higher, as desired. Frame is elevated by turning crank with one hand, no great strength is required. Patient is raised without jar or strain. Changing of bed linen, use of bed-pan, bathing of patient, dressing of wounds accomplished with minimum effort, when frame is elevated, by removal and replacement of canvas slings, one at a time (Langworthy).

Avenue, New York. This antitoxin has given encouraging results according to various observers.

A SAMPLE LABEL FROM THE CONTAINER USED AT THE LEDERLE ANTITOXIN LABORATORIES

100 C.C. .2112

TETANUS-PERFRINGENS ANTITOXIN

(Hygienic Laboratory Standard)

Each c.c. contains

..... **Units Perfringens Antitoxin**

..... **Units Tetanus Antitoxin**

LAB. NO. Potent until

INDICATIONS

Gas gangrene, caused by infection with Bacillus Welchii

DOSAGE

Prophylaxis: 10 c.c. subcutaneously.
Treatment: 500 c.c. intravenously as follows: Initial dose, 200 c.c. followed in six to eight hours by 100 c.c., and every twelve hours thereafter by 100 c.c. as required.

LEDERLE ANTITOXIN LABORATORIES

511 Fifth Avenue **New York City**

The serum has not been used in a sufficient number of cases to allow of definite conclusions or to establish a very definite procedure. However,

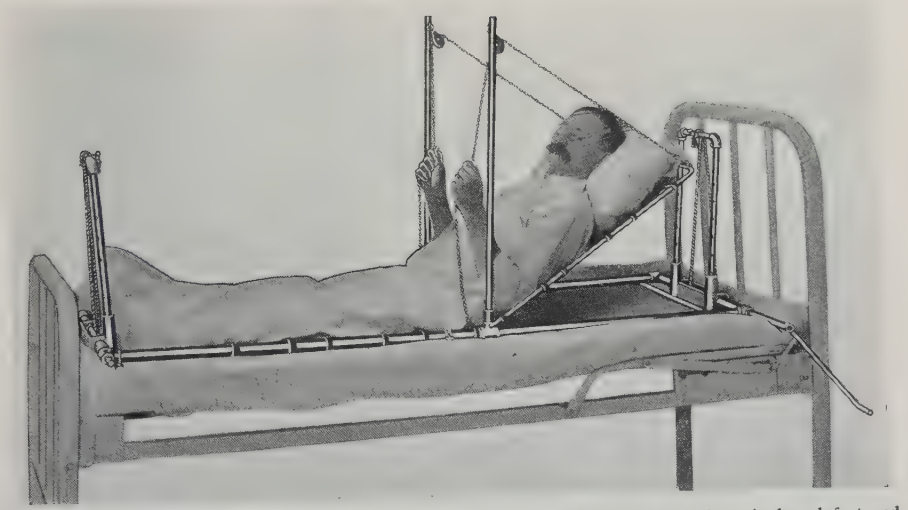


Fig. 1099.—Showing back-rest, which patient can adjust himself. This can be raised and fastened at any desired height, and lowered at will, by any patient who can use his arms. If back-rest, with the two vertical posts which support it, are not desired, they can be removed. The canvas slings which are on the back-rest are then placed on the frame itself (Langworthy).

large doses intramuscularly for prophylaxis and large intravenous doses for treatment may with safety be employed (Bull).

If there is involvement of much devitalized tissue the serum cannot be expected to do more than temporarily counteract the systemic intoxication (Bull).

Two facts of importance should be noted, the temperature is usually low, as compared with the rise in the pulse. This variation becomes more marked as the case progresses. The degree of pain is excessive for the

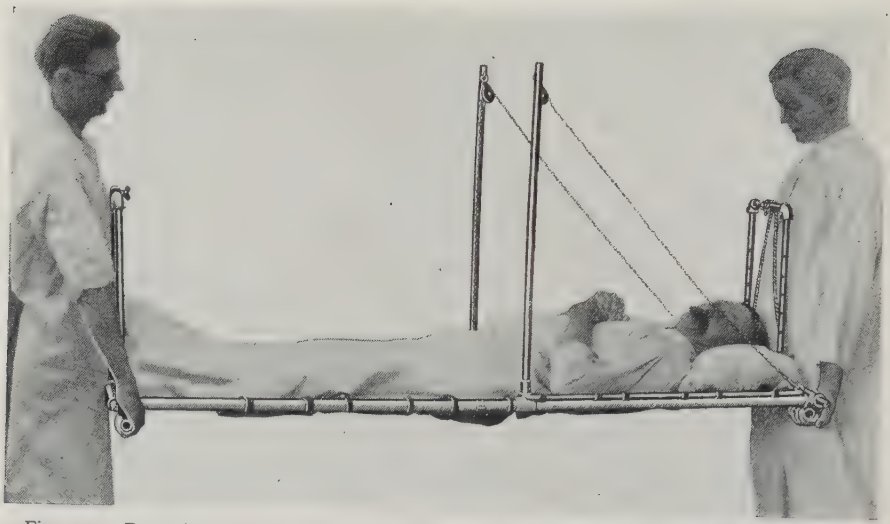


Fig. 1100.—Frame is portable, like a stretcher. Patient can be lifted on it, carried about, or placed on stretcher cart, and wheeled to operating room, to *x*-ray department, or sun-room, and then returned to bed, without being moved or strained (Langworthy).

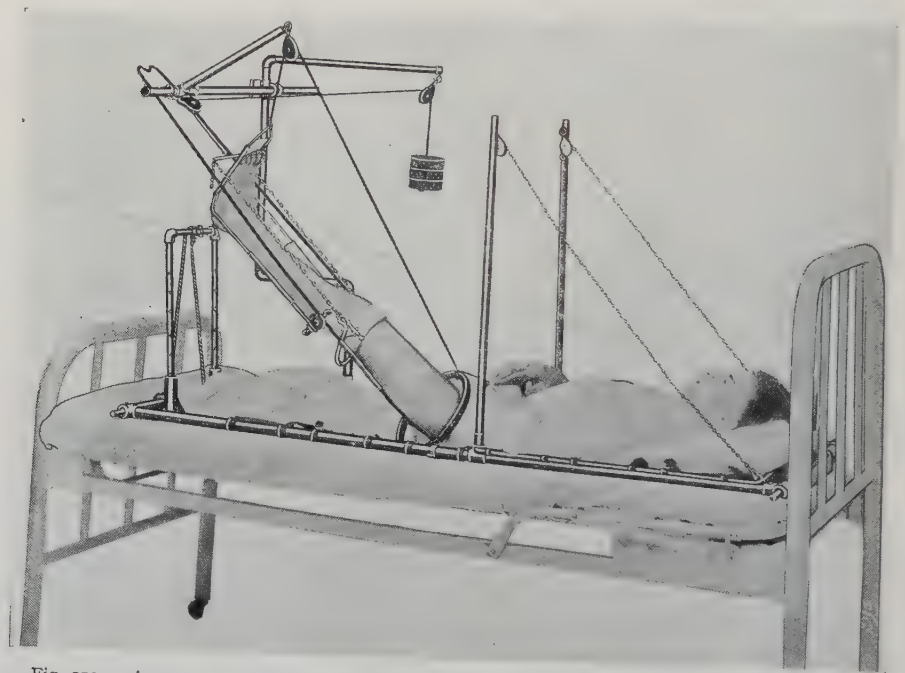


Fig. 1101.—Apparatus for extension and suspension treatment of femur fractures attached to elevator frame. Suspension of the lower extremity in any position desired is obtained by the proper arrangement of one vertical and one horizontal bar. Extension by caliper, pin, or adhesive tape is provided for by fixtures permanently attached, and always in the proper place, on the vertical and horizontal bars. Note in this and following pictures that extension by caliper is being applied to lower end of femur. This caliper permits complete extension, as well as flexion, of the knee-joint. Note also that the extension weights are always hung where nothing will interfere with their pull, where they will not be bumped into, and where they will help to balance the entire apparatus. The bar which supports them can be swung around to any desirable position (Langworthy).

extent of the lesion. Both these facts may be of early diagnostic value (Pilcher).

Local Treatment.—In cases of the *first stage*, while the infection is local and superficial, the devitalized muscle should be removed, the wound left open, the muscle planes opened up, held apart by a single layer of gauze (no gauze packing should be used), and Carrel tubes well placed and spaced. Instillation should be made of quino-formol solution hourly or two hourly as in the ordinary Carrel-Dakin treatment.

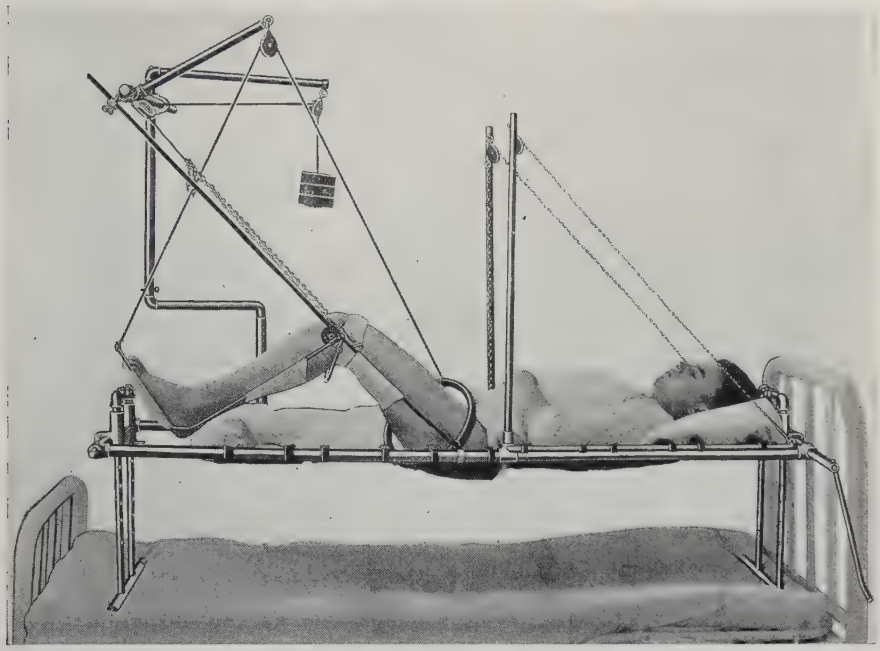


Fig. 1102.—Entire apparatus elevated 15 inches above bed. Elevator frame and suspension and extension apparatus for femur fractures form one unit. Patient is raised without any disturbance or change of fracture apparatus. In this position patient's back can be bathed completely by taking out one canvas sling at a time. Bedding can be changed completely. Patient can then be lowered to comfortable position on bed-pan, and back-rest can be raised to make more comfortable. All can be done by one nurse with little effort. All can be done without any movement or strain of patient. Flexion of knee is shown here. Movements of knee can be made by patient when desirable by means of rope, which is shown tied to Thomas splint (Langworthy).

In the *second stage* resection of the entire muscle affected is indicated. The resection should go into viable tissue, detectable by the color, contractibility, and the bleeding present (Pilcher). All parts should be freely opened and rendered accessible to the antiseptic. The fear of infecting normal tissues appears negligible and antiseptic inundation apparently precludes it (Pilcher).

Amputation may at times be indicated (Fortuine-Vickers) when the case is seen in the *terminal third* late stage because it has been neglected or inadequately treated. Immediate liberation, opening up of the involved areas, is demanded. The question of amputation will come up. Shock of

an amputation will kill certain of these cases. Conservative treatment consistently carried out will save many limbs hitherto sacrificed. The absorption of toxins must be stopped and it will be a matter of nice surgical judgment which will decide whether an amputation is the sine qua non or whether conservative treatment may be safely continued.

Quino-formol Solution for Disinfecting Gas Gangrenous Wounds (Pilcher).

Quinin sulphate	1 gm.
Hydrochloric acid	0.50 c.c.
Glacial acetic acid	5.00 c.c.
Sodium chlorid	17.50 gm.
Formol	1.00 c.c.
Thymol	0.25 c.c.
Alcohol	15.00 c.c.
Aqua	q. s. ad. 1 liter

1. Dissolve quinin in HCl and acetic acid.
2. Dissolve sodium chlorid in the water.
3. Dissolve the thymol in the alcohol.

Add No. 1 to No. 2, then add to the formol, and then No. 3. To be used as Dakin's solution in treating gas gangrene.

It is unirritating, stable, easy to prepare, deodorant. It causes fluid to flow from the tissues, hence it diminishes edema and pain.

It is not proteolytic, consequently, when infection is checked, Dakin's solution should be resumed to remove detritus and slough.

FAT EMBOLISM

Fat embolism, to a greater or less degree, exists in every case of fracture. Free fat, open venous channels, and a force to drive the fat are essential to the production of fat embolism. It is most evidently present in those cases associated with great laceration of tissue and in open fractures. The soft fat of the medullary tissue is the source of the fat-drops that, getting into the venous circulation, are carried directly to the pulmonary capillaries, where they lodge unless the blood-pressure is sufficient to force them out of the lung capillaries on into the systemic circulation. They then lodge in the brain, kidneys, or other organs. The oil is removed from the circulation by oxidation and saponification, by a phagocytic action of the leukocytes, and directly by the liver and kidney. The danger in fat embolism is twofold: that the patient may die from asphyxiation, due to the imperfect oxygenation of the blood because of the rapid occlusion of the pulmonary capillaries with fat globules, and that he may die from cerebral complications.

Symptoms: There are, therefore, two varieties of cases clinically, the pulmonary and the cerebral, according as lung or brain complications predominate.

The *pulmonary type* will present rapid respiration, dyspnea, pallor, and then cyanosis, followed by a weak circulation and the signs of pulmonary edema, the expectoration of a bloody, frothy mucus, along with the physical signs of edema of the lungs.

The *cerebral type* presents fewer pulmonary signs, but chiefly delirium, restlessness, stupor, and finally coma and possibly convulsions. There are rarely signs of any focal disturbance in the brain. The urine should be

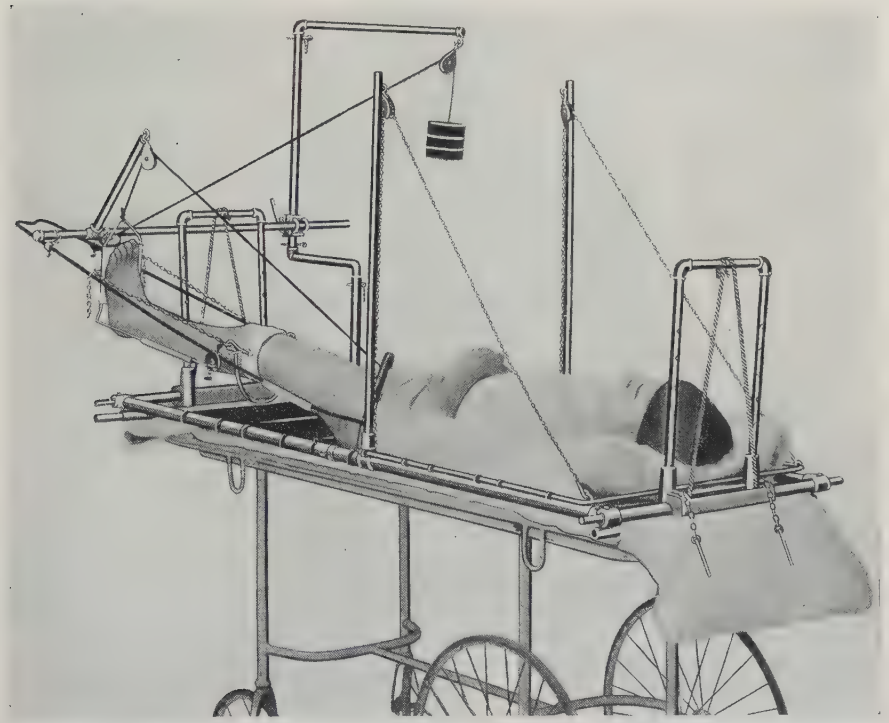


Fig. 1103.—Entire apparatus forms a portable unit. In this picture the patient in the elevator frame, with fracture apparatus in use, has been lifted on to the stretcher cart, as for transportation to *x*-ray department, operating room, or to porch for light and air. It is possible to be able to perform certain surgical operations while the lower extremity is suspended and while extension is maintained. This apparatus can be placed directly on the operating table with the patient in it, and then can be carried back to the bed without disconnecting or rearranging anything. If a half-ring Thomas splint instead of the full ring splint is used, it can be removed during the operation without interfering with the extension, and then replaced following the operation. The details of the elevator are well shown at the head end of this picture. A double wire cable is wound up on an axle by turning a crank which fits over the projecting end of the axle. The frame slides up on two upright posts. The frame is held at various heights by inserting small metal pins (which are shown lying on the end of the stretcher pad) into small holes in the two uprights (Langworthy).

examined for fat and albumin. The eye-grounds should be examined to detect hemorrhages and the changes of choked disk.

Diagnosis: Shock, acute pulmonary lesions from other causes than fat embolism, acute urinary suppression, ordinary embolism, and traumatic hemorrhage—all should be distinguished from fat embolism. Keeping in mind the two pictures of fat embolism and their salient characteristics it will be difficult to confound these others lesions with it.

Treatment: Stimulation of the heart for its extra work is indicated. Immobilization of the fractured part to prevent more fat from getting into

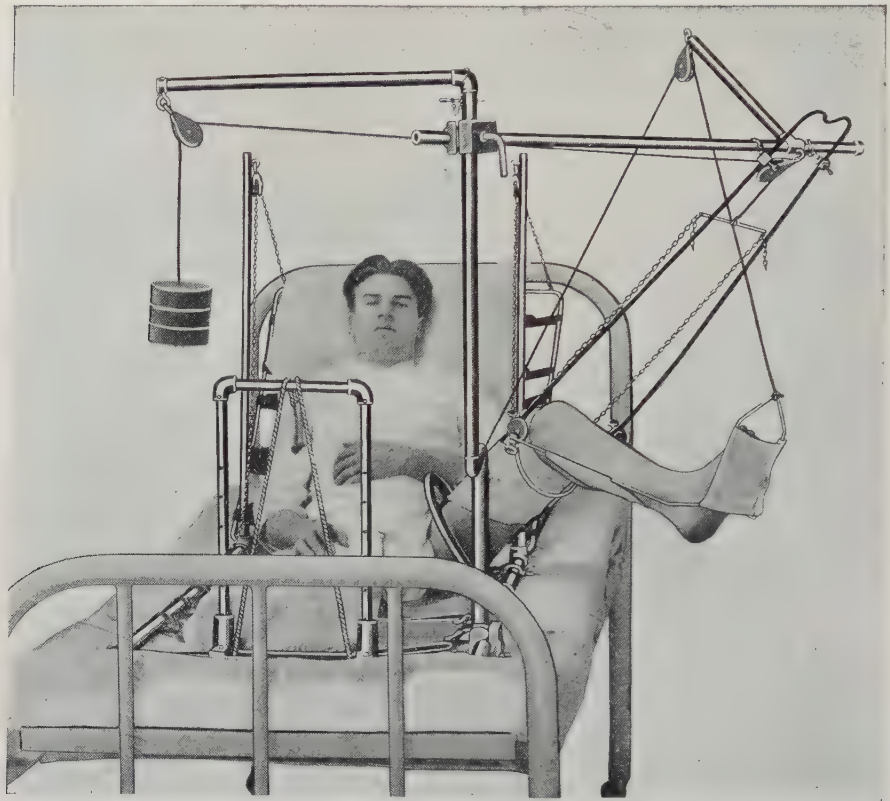


Fig. 1104.—Position of wide abduction of thigh. Complete vertical extension of the entire lower extremity can also be secured if desired. In fact, the apparatus is designed so that every possible position of the thigh and leg can be obtained. The vertical bar is clamped anywhere desired on the frame. The horizontal bar is clamped anywhere desired on the vertical bar. An extension is also provided for the vertical bar, so that the necessary height for complete vertical extension in an adult can be obtained. This is extremely useful at times for fractures of the upper third of the femur, and in those where complete flexion of the knee may be needed. Patient shown here with back-rest raised (Langworthy).

the circulation and the administration of oxygen to relieve asphyxia are important in the treatment.

CHAPTER XVII

FRACTURES OF THE PATELLA

Anatomy.—A knowledge of the anatomical relations of the patella is necessary to a perfect understanding of the fractures to which it is liable (Figs.

Fig. 1105.—Anterior view of normal patella.

1105–1107). Attached to the patella upon its upper border is the tendon of the quadriceps extensor muscle. Upon each side of the bone are attached

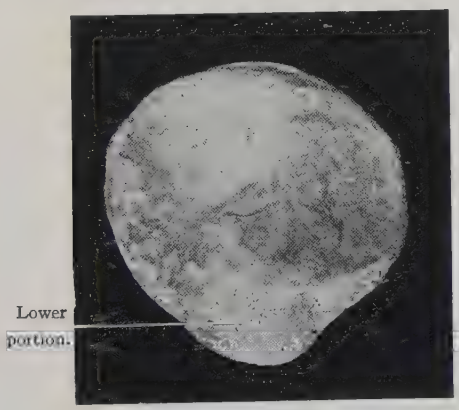


Fig. 1106.—Posterior view of normal patella, showing the two articular surfaces for the condyles of the femur. Note the lower tip of patella is extra-articular.

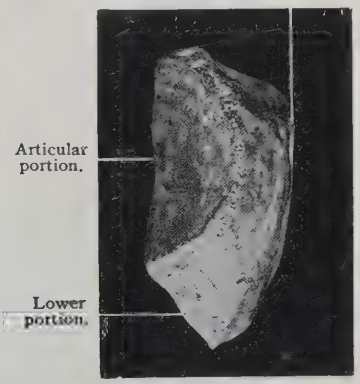


Fig. 1107.—Lateral view of normal patella. Note lower portion, extra-articular. Fracture in this lower portion will not open the knee-joint.

the vastus internus and vastus externus respectively. Below the insertions fo the vasti is a portion of the low attachment of the fascia lata of the thigh.

At the lower border of the patella is the patellar tendon. This tendon is inserted into the tubercle of the tibia, and it is separated from the head of the tibia by a bursa and a pad of fat tissue. The tendon of the quadriceps, the insertions of the vasti muscles, and the patellar tendon are all continuous with the strong fascia lata surrounding the thigh. The fascia lata is attached below to the condyles of the femur, the sides of the patella, the tuberosities of the tibia, the head of the fibula, and to the deep fascia of the leg in the popliteal space. The patella is seen, therefore, to lie in a strong fibrous sheath that encircles the knee and is attached to various bony prominences. The synovial membrane of the knee-joint lies directly beneath and attached to the posterior surface of the patella. Laterally and posteriorly the synovial membrane lies next to the encircling fascia of the joint. The deep bursa of the femur lies in front of the lower end of the femur beneath the quadriceps muscles, and often communicates with the knee-joint. The tubercle of the tibia is on a level with the head of the fibula. The outline and anterior surface of the patella can be palpated throughout. When the leg is completely extended and is at rest the patella can be moved from side to side. The numerous longitudinal striæ on the anterior surface of the patella can be detected. In these the tendinous bundles of insertion of the rectus are embedded. It is these fibers that fold in over the broken patella and prevent the approximation of the fragments. The ligament of the patella is parallel with the axis of the leg.

Fracture of the patella occurs through either muscular contraction and strain, a "tear fracture," or through direct violence, a "blow fracture." The form of the fracture is not altogether dependent upon the causative force. The "tear fracture" will be transverse and clean cut, the "blow fracture," comminuted and irregular. The knee-joint is generally opened, *i. e.*, the synovial membrane is generally torn. The synovial membrane is reflected from the posterior surface of the patella some distance from the most inferior tip of the bone. It is possible, therefore, for a fracture to occur at the lower portion of the bone for some considerable distance from the lower edge without opening the knee-joint. A longitudinal fracture of the patella may occur. Following injury to the knee it should not be overlooked. A persistent joint effusion or recurring joint effusions from slight injuries or overexertion may suggest the true condition to be a longitudinal fracture of the patella and not primarily a chronic arthritis.

An Anomaly of the Patella.[1]—The patella, being a sesamoid bone, is liable to various anomalies in development common to sesamoid bones in other parts of the body.

In the anomalies reported the appearances are similar, viz., the outer and upper quadrant of the patella, which is always the part involved, consisted of one or two separate fragments of bone. The general contour of the patella otherwise remains normal.

The separate fragments of bone have the same structure as the main portion of the patella (see Fig. 1108).

[1] Adams and Leonard, Surg., Gyn., and Obst., 1925.

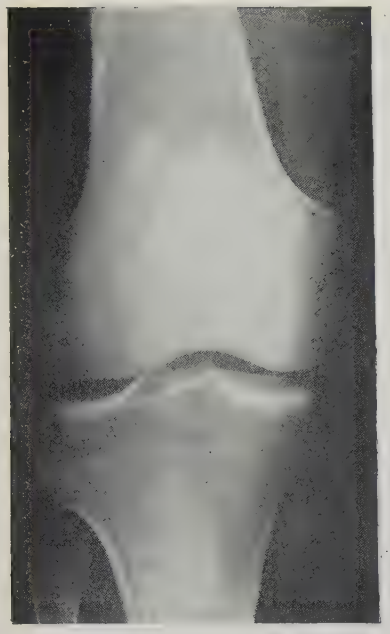


Fig. 1108.—Roentgenogram of knee to show a congenitally abnormal patella (John Adams).

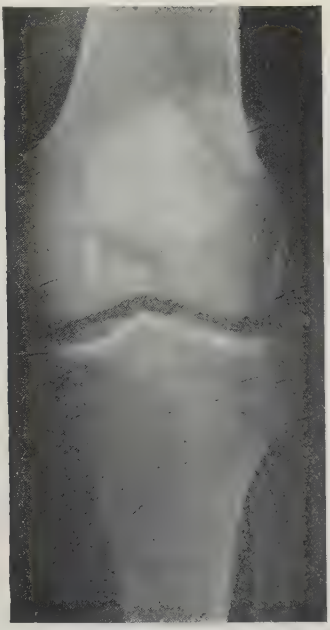


Fig. 1109.—Roentgenogram of knee to show a congenitally abnormal patella. This is the opposite knee to that shown in Fig. 1108. These congenital deformities of the patella are usually bilateral (John Adams).

Fig. 1110.—A roentgenogram of knee-joint. Note a congenital variation anomaly of the patella. This may be mistaken for a fracture of importance, particularly in industrial injuries (John Adams).

In one series (Adams and Leonard) of 63 fractures of the patella seen in one year over 3 per cent. were congenital anomalies. The occurrence of the anomaly is more common than has been supposed.

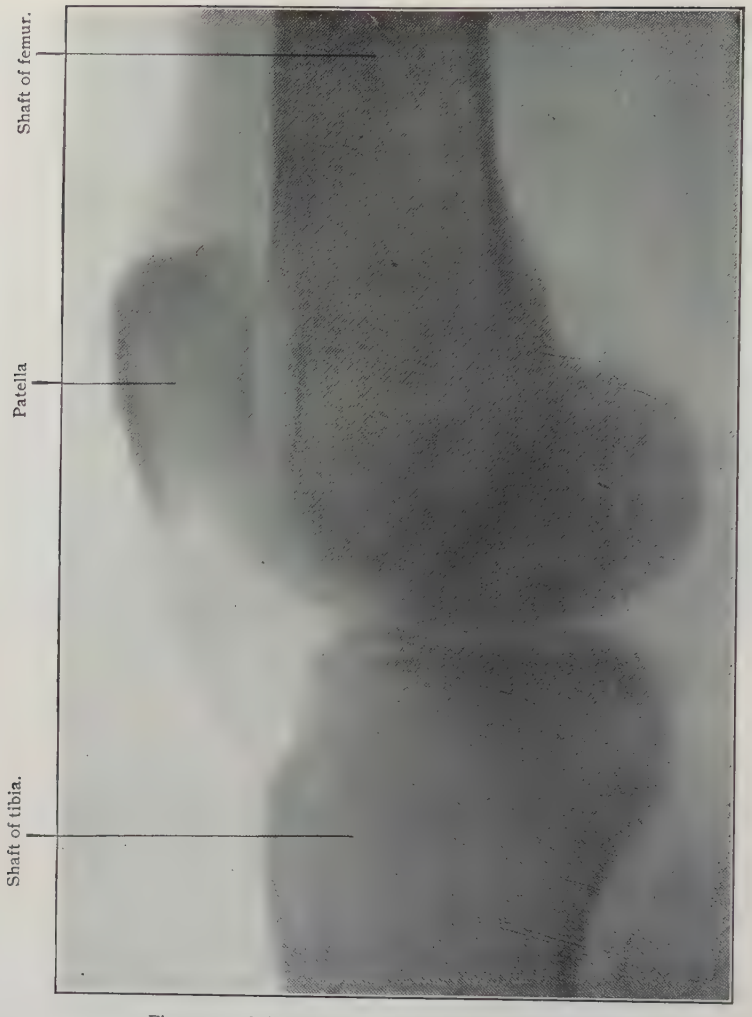


Fig. 1111.—Skiagraph of normal right knee-joint in an adult.

Fig. 1112.—Right knee normal; left knee, fracture of patella. Two days after accident. Observe swelling of whole knee. Joint filled with fluid.

The *differential diagnosis* between an anomaly and fracture may be made from careful Roentgen-ray plates taken of both knees. These anomalies are usually bilateral. The adjacent surfaces of the fragments are smooth and appear like cortical bone.

The anomalies are situated in the outer upper quadrant of the patella. This is an unusual place for fracture. The absence of an adequate accident to cause fracture is important. The recognition of this congenital anomaly is especially important in dealing with industrial compensation injuries (Adams and Leonard).

One case well authenticated is recorded by Petty, Buenos Aires,[1] of a congenital *horizontal* division occurring in both patellæ.

Symptoms.—There are pain in the knee and immediate disability, varying from partial to complete loss of power in extension and in flexion. Inability to extend the leg is suggestive of either a fracture of the patella, a rupture of the patella ligament, a rupture of the quadriceps tendon, or it may be associated with a fracture of the beak-shaped process of the upper part of the tibia—the tibial tubercle. The patient may be unable to rise or, if he can stand, he cannot move except backward, and then only by dragging the foot of the injured limb upon the ground. The patient is often unable to raise the heel from the bed when lying upon the back. Swelling of the knee, which at first is slight, after three or four hours may become very great (Fig. 1112). The swelling is due to the accumulation of blood and synovial fluid in the knee-joint. A traumatic synovitis exists. The immediate swelling of the knee rarely may become great enough to demand an incision to relieve the tension upon the skin, to prevent sloughing of the skin above the broken patella. Immediately after the accident crepitus may be elicited by pressing the two fragments together. When the knee-joint is distended by fluid it is often impossible even to detect the fragments of the patella, but as the fluid subsides and the sulcus between the bones is felt crepitus can again be detected. The degree of the separation of the fragments is dependent upon the amount of distention of the joint and upon the extent of the tearing of the lateral aponeurosis (fascia lata) of the knee, permitting muscular contraction and retraction. If the causative violence is associated with a wound of the soft parts there will be evident a contusion or an abrasion of the skin or a lacerated wound opening the knee-joint, making the fracture an open one.

Treatment.—The indications to be met are the limitation and removal of the effusion, the reduction of the fragments, the maintenance of the reduction until union is satisfactory, and the restoration of the functions of the joint to their normal condition.

The Limitation and Removal of the Effusion.—If the fracture is seen before there is great swelling, limitation of the swelling may be effected by immobilization of the knee and the accurate application of an elastic rubber bandage. If the bandage is not at hand, sponge compresses may be used, viz., two slightly moistened bath or carriage sponges are allowed to

[1] Brit. Jour. Surg., April, 1925.

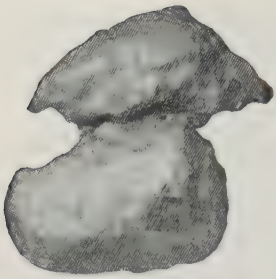


Fig. 1113.—Fracture of the patella; fibrous union. A growth of bone has taken place about the lower fragment (Warren Museum).

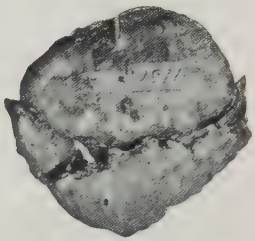


Fig. 1114.—Fracture of the patella. Note fracture of lower fragment. A common form of fracture (Warren Museum).

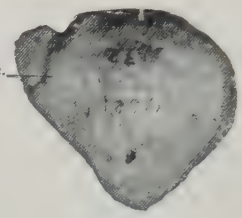


Fig. 1115.—Fracture of the patella (Warren Museum).

Fig. 1116.—Fracture of patella; union with long fibrous band. Note separation of fragments (Warren Museum, Specimen 5253).

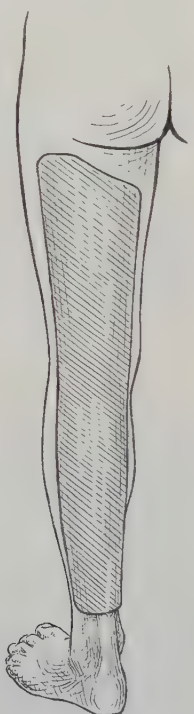


Fig. 1117.—Ham-splint without strap, showing proper length and relation to thigh and leg posteriorly (Cotton).

dry under pressure sufficient to flatten them. These are placed upon each side of the knee and over it, and are held by a few turns of a roller bandage. Cool water is then poured over the whole. As the sponges absorb the water they enlarge, causing equable and firm pressure on the knee, thus very materially hindering the accumulation of fluid and favoring its absorption. These wet sponge compresses should be left in position for from twelve to twenty-four hours, and then a fresh set used.

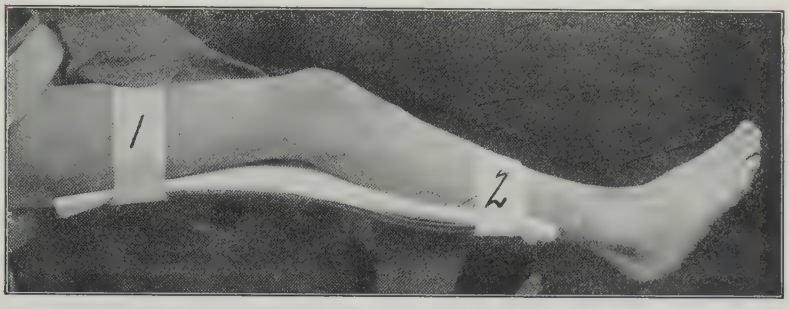


Fig. 1118.—Improper method of applying a ham-splint. The knee-joint is not immobilized. Flexion is possible. Straps 1 and 2 are insufficient.

Massage skilfully applied to the whole limb, irrespective of the method of treatment eventually instituted, will not only assist in the absorption of the fluid, but will preserve intact the muscles of the limb. Massage to be effective should be applied at least twice daily, and from fifteen minutes to half an hour at a time. Slight pain will be felt, but after a time massage will be painless and give great comfort.

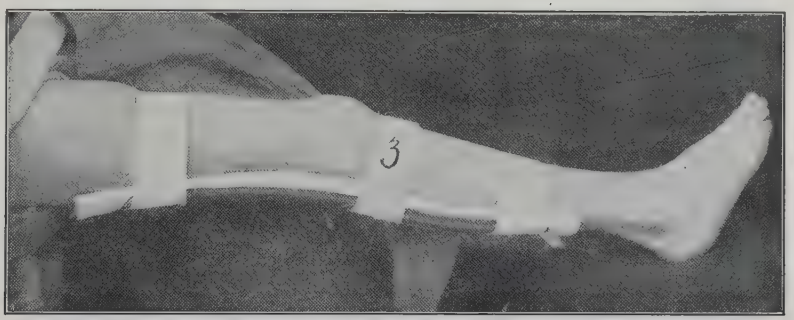


Fig. 1119.—Proper method of applying a ham-splint. The third adhesive-plaster strap (3) prevents flexion of the knee.

The Reduction of the Fragments.—No attempt should be made to reduce the fragments until nearly all the fluid is removed from the knee-joint. Reduction is accomplished by immobilization of the knee-joint, by fixation of the lower fragment, and by traction upon and fixation of the upper fragment. The leg should be extended completely and the knee immobilized either upon a ham-splint (Figs. 1117–1119) or upon a Cabot posterior wire splint. The ham-splint is preferably made from a plaster-of-Paris bandage.

The fragment is held fixed by a strap, preferably of adhesive plaster, placed obliquely about the leg and splint, and fastened to the splint above the fragment (Figs. 1120, 1121, 1123, 1124). The upper fragment is drawn down first by elevation of the leg upon an inclined plane, which relaxes the quadriceps extensor muscle, then by traction obtained by a strap passed

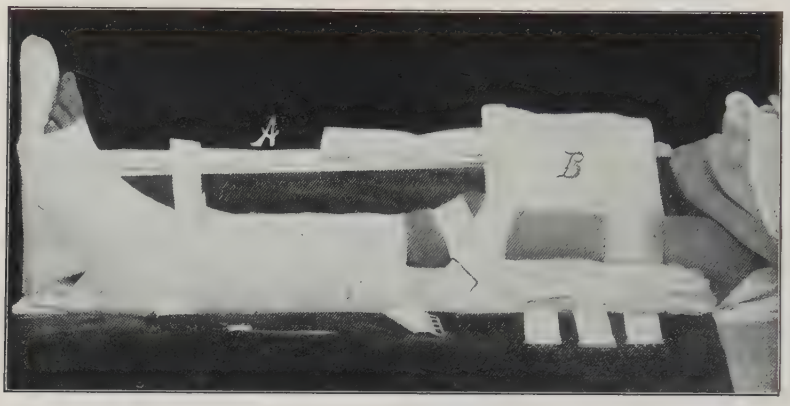


Fig. 1120.—Expectant method of treating fracture of the patella. Leg extended on posterior wire splint. Fragments held by two straps. Fluid has left the joint. *A*, Side splints; *B*, coaptation splints reflected.

obliquely above the upper fragment and fastened to the splint below the fragment. The upper strap will need repeated adjustment as the plaster slips and as the fluid disappears from the joint. To facilitate traction by this upper strap the quadriceps muscle should be held firmly by coaptation

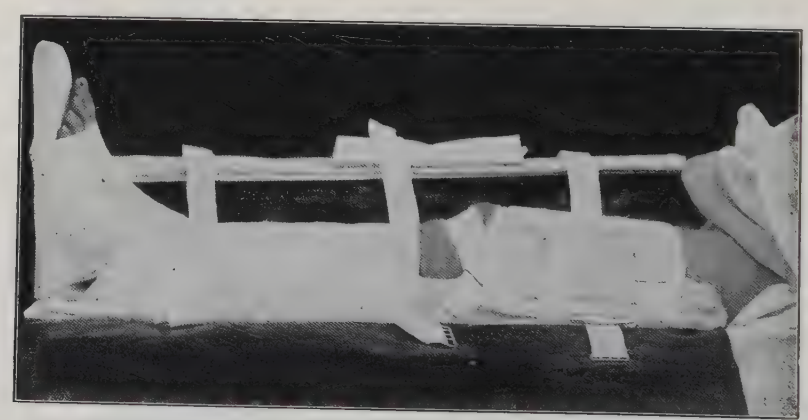


Fig. 1121.—Expectant method of treating fracture of the patella. Same as Fig. 1119, with the addition of coaptation splints to the thigh, padding, and straps.

splints and straps encircling the posterior splint. The quadriceps cannot then actively pull upon the upper fragment. The tendency of these two straps thus applied will be to tilt the broken surfaces of the two fragments upward and apart, particularly if there is fluid in the joint. It is important, therefore, to place a third strap over the two broken edges of the fragments

in order to hold them down to their proper level and to assist in bringing them into apposition. The coaptation splints should be removed at every massage treatment, the upper fragment being steadied by an assistant. The straps about the patella need not be removed during the massage.

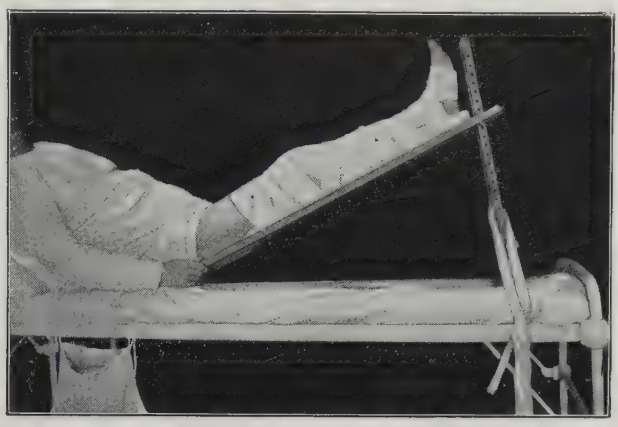


Fig. 1122.—Fracture of patella, dressed on inclined plane (Ashhurst).

They will be of no inconvenience. As soon as the effusion has left the joint, all will have been gained in the reduction of the fracture that can be gained by this method.

Aspiration of the knee-joint by means of a narrow knife incision or by means of a large-sized trocar is, if done under strictly antiseptic precau-

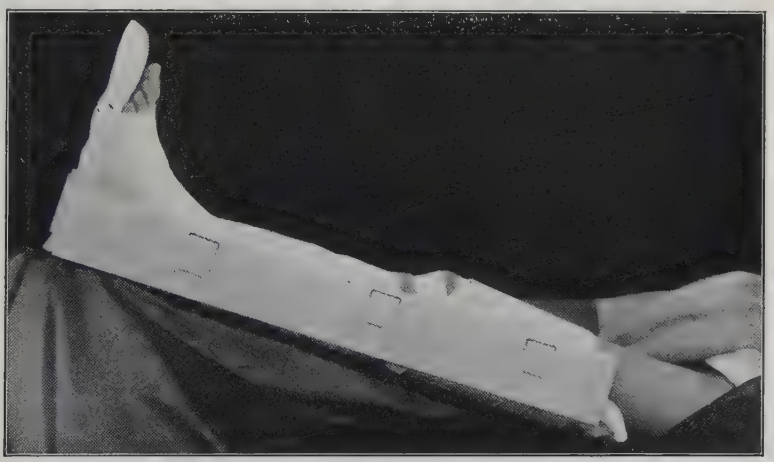


Fig. 1123.—Expectant method of treating fracture of the patella. Same as Fig. 1121, with the addition of two lateral splints, padding, and straps. A posterior wooden splint, seen better in Fig. 1121, and elevation of the limb.

tions, and forty-eight hours after the fracture, often satisfactory in immediately removing the bulk of the effusion; if firm compression is then made, it effectually prevents the reaccumulation of fluid.

Maintenance of Reduction Until Union is Satisfactory.—At the end of about four or six weeks from the time of the injury union will be found. All fluid will have left the joint. The retentive straps and coaptation splints may now be removed. The leg should be immobilized by means of a plaster-of-Paris splint extending from just below the swell of the calf to the groin. This splint is split on the side or posteriorly and arranged as a removable splint. Proper bathing is facilitated. This enables the masseur to work.

The removable splint is made thus: A light-weight plaster-of-Paris roller bandage is applied to the properly protected leg from above the ankle

Fig. 1124.—Expectant method of treating fracture of the patella. Anterior view of apparatus complete. The padding of the side splints is shown.

Fig. 1125.—Extent of flannel bandage to knee, applied after all immobilizing apparatus is removed. The bandage is started at 1.

to the groin. It is split in the median line its whole length before the plaster has quite hardened. It is sprung off the leg. After it is hard a narrow strip of leather, upon which are fastened lacing hooks, is stitched to each cut edge. This splint may now be sprung on the limb and laced snugly in position. A leather splint may be similarly made from a plaster cast and mold of the limb. As soon as union is firm the patient should be up and about with the light removable fixation splint applied, walking with the aid of crutches.

Fixation (prevention of flexion and extension) on walking is to be maintained for at least six months after the injury. Protecting the knee thus

when walking for this period of six months does not preclude active movements of the knee when not bearing weight upon the limb. At the end of

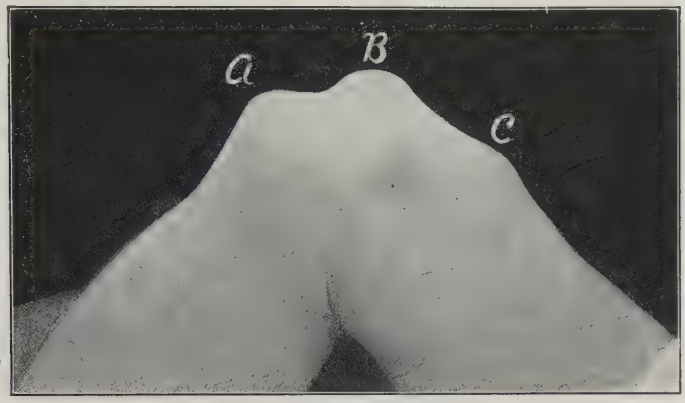


Fig. 1126.—Old fracture of patella; great separation of fragments. Condyles of the femur are prominent between fragments. Leg was useful, but weak. *A*, The lower fragment; *B*, the condyles of the femur; *C*, the upper fragment.

that time the patient may be allowed to go about with a cane and a snugly fitting roller bandage (see Fig. 1125). This bandage should be made of me-

Fig. 1127.—Fracture of the patellæ. Moderate separation of the fragments of each knee-joint. Useful legs.

dium weight flannel, cut straight with the weave, and not on the bias. The bandage should be applied from the middle of the calf of the leg to the middle of the thigh when the leg is completely extended. As the patient becomes

confident of his strength the cane need not be carried. Sudden movements are to be avoided. At the end of six or eight months, varying with the individual case, all support may be omitted from the knee.

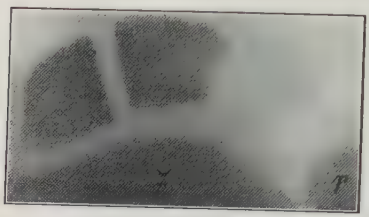


Fig. 1128.—Transverse fracture of the patella at its middle, remarkably clean cut.

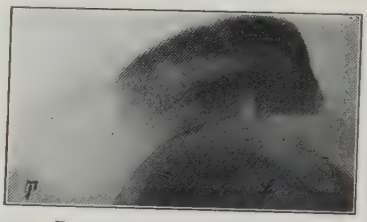


Fig. 1129.—Transverse fracture of the patella, union solid.

The Restoration of the Function of the Joint.—From the day of the injury daily massage to the whole limb is important. It maintains the muscles in good tone. It prevents adhesion of the fragments to the tissues about the

Fig. 1130.

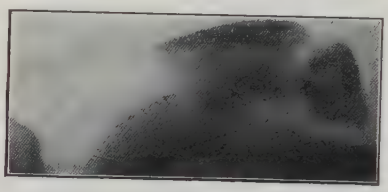


Fig. 1131.

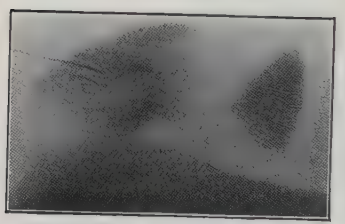


Fig. 1132.

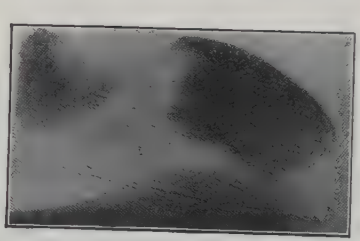


Fig. 1133.

Fig. 1134.

Figs. 1130–1134.—Types of fracture of the upper third of the patella. Note tilting of fragments.

condyles of the femur, a not uncommon cause of ankylosis of the joint. It facilitates the absorption of the effusion of blood and synovial fluid. After the second week daily active motion is to be instituted; at first very slight

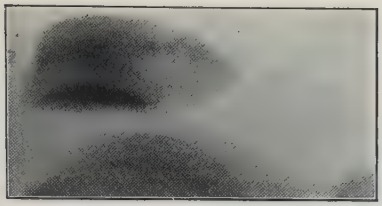


Fig. 1135.

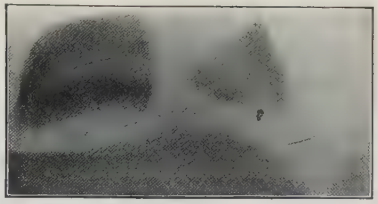


Fig. 1136.

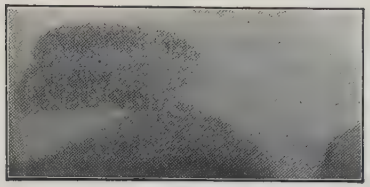


Fig. 1137

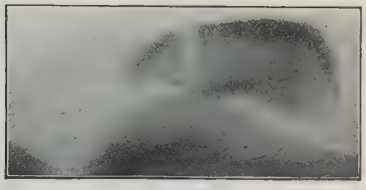


Fig. 1138.

Fig. 1139.

Figs. 1135–1139.—Types of fractures of the lower third of the patella. Figure 1139 is an unusual type of fracture of the anterior portion of the lower third.

Fig. 1140.

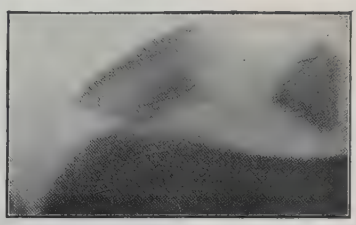


Fig. 1141.

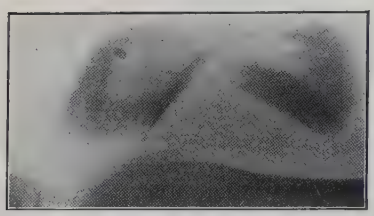


Fig. 1142.

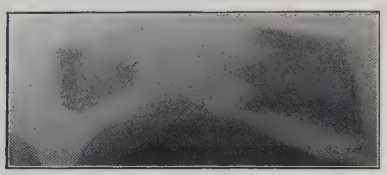


Fig. 1143.

Figs 1140–1143.—Illustrating types of tilting or displacement of the fragments in a fracture of the patella.

indeed, barely 2 or 3 degrees. The patient may walk about on the injured leg with knee fixed after the second week. If the relative position of the fragments is not altered perceptibly by this passive motion and lasting pain

is absent, it may be persisted in with regularly increasing amounts. At the expiration of eight or ten weeks active motion at the knee-joint may cautiously be allowed. The appearance of persistent and increasing tenderness, sensitiveness, or pain, and increasing separation of the fragments are the indications to diminish or cease passive and active motions.

Summary of the Treatment of Fracture of the Patella by the Expectant or Non-operative Method.—During two weeks' fixation of the knee elastic compression, douching, massage, the thigh flexed slightly on pelvis, the

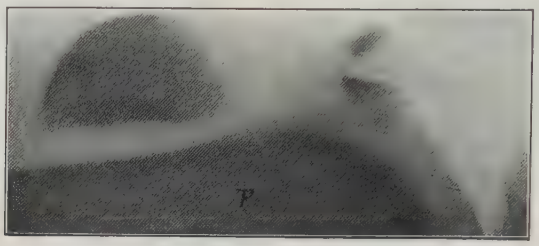


Fig. 1144.

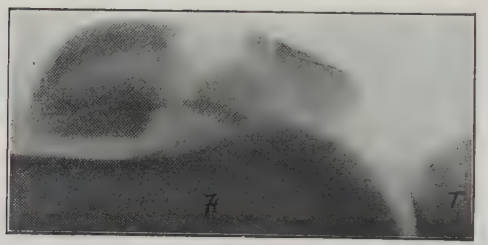


Fig. 1145.

Fig. 1146.

Figs. 1144–1146.—Fracture in lower third of patella. Note comminution of lower fragment.

leg extended, retentive straps, and coaptation splints are the measures employed. At the third or fourth week remove all apparatus, apply removable splint, allow walking with crutches, and use daily active motion. At the eighth week discard crutches, use cane, and permit limited daily active motion. At the fourth month discard splint, apply flannel bandages, and discard cane. At the sixth to the eighth month remove all support.

Open Fracture of the Patella.—This is a very serious injury, because one of the largest synovial cavities of the body is exposed to infection. The

edges of the superficial wound should be refreshed. It is safest and wisest to lay open the knee-joint, to thoroughly irrigate it with a sterilized normal salt solution. All blood-clots should be carefully wiped away. All

Fig. 1147.—Comminuted lower fragment of patella.

loosely attached fragments of bone should be removed. Particular attention should be paid to the posterior parts of the joint behind the condyles of the femur. It will be found convenient in cleaning these parts first to

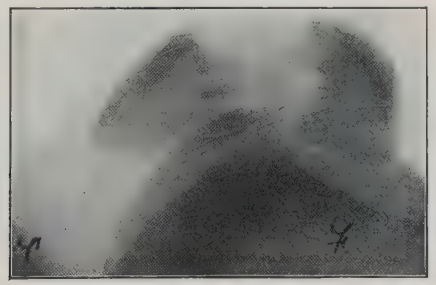


Fig. 1148.—Comminuted fragments between the main fragments.

flush the joint with sterile salt solution and to flex and to extend the knee. All parts of the joint posteriorly are thus likely to be thoroughly flushed. The fragments should be approximated and sutured by some absorbable

Fig. 1149.—Much comminuted fracture of the patella. Best treated by an encircling absorbable suture to bring fragments together.

suture. The skin wound should be closed. The knee-joint should be immobilized in a posterior wire splint and side splints or in a plaster-of-Paris splint.

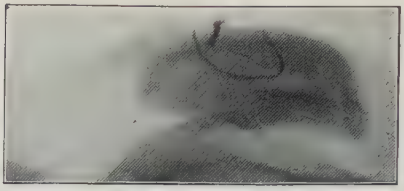


Fig. 1150.

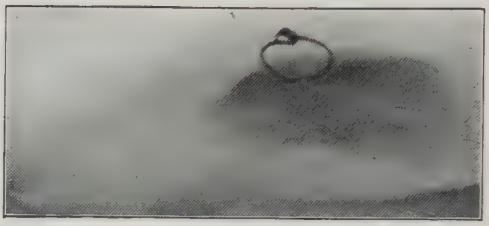


Fig. 1151.

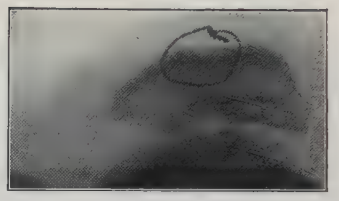


Fig. 1152.

Figs. 1150-1152.—After suturing fracture of the patella by wire, the old operation. Note the lack of exact approximation upon the joint side of patella.

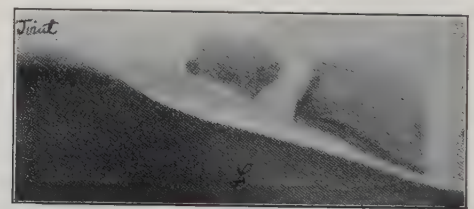


Fig. 1153.—Old fracture of the patella with great separation and retraction of the fragments and rupture of the patella tendon or ligament. Note atrophy of the patellar fragments.

Fig. 1154.—Old fracture of the patella. Note absence of bony union of unreduced fragments.

Prognosis.—Ordinarily, an individual should not follow his occupation for about six weeks to two months after a fracture of the patella, *i. e.*, unless the occupation can be conducted with a leg held stiffly at the knee. The functional usefulness of the limb and not anatomical considerations should be the chief criterion in determining the result following fracture of the patella. If a man can earn his living as before the accident without local discomfort or hindrance he possesses a useful limb. It makes little difference if there is a slight separation of the fragments or a suggestion of a limp

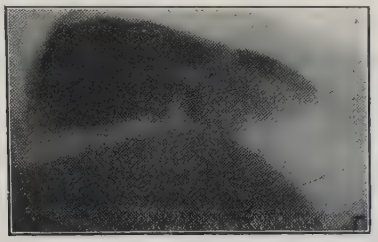


Fig. 1155.

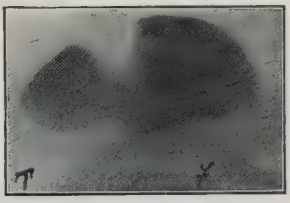


Fig. 1156.

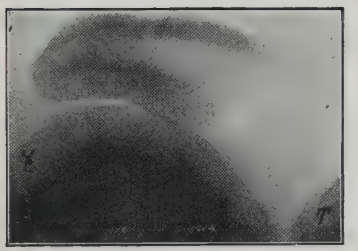


Fig. 1157.

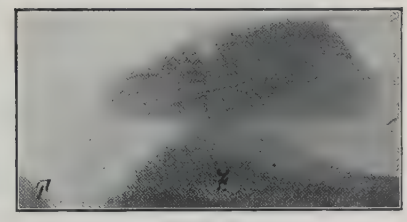


Fig. 1158.

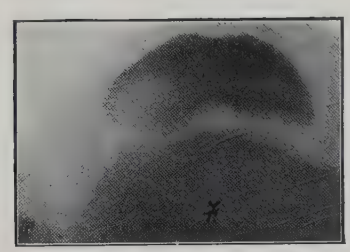


Fig. 1159.

Figs. 1155–1159.—Types of old fracture of the patella. Note the irregular joint surfaces on the under side of patella.

or slight atrophy of the thigh and calf muscles; these conditions are all to be accepted as part of the irreparable damage, and are trivial. In non-operative cases the union is sometimes fibrous, although it may be bony. The interval between the fragments may amount to 5 or 6 inches. The approximation of the fragments of the patella is not evidence of strength, for the fibrous bond of union may be much narrower than the fractured surface and very thin, and thus easily ruptured. The usefulness of the limb after fracture

of the patella is not dependent upon any one factor, either the kind of union or the extent of the separation of the fragments of bone. There are usually no adhesions of the upper fragment to the femur; but injury to the bursa under the quadriceps may cause troublesome adhesions upon the anterior surface of the thigh. Full flexion is a common result, but there is often limitation of active extension. There may remain a little joint stiffness, despite both massage and active and passive motion; this, unless due to fibrous adhesions, disappears gradually. The majority of cases of fracture of the patella under careful non-operative treatment will secure a

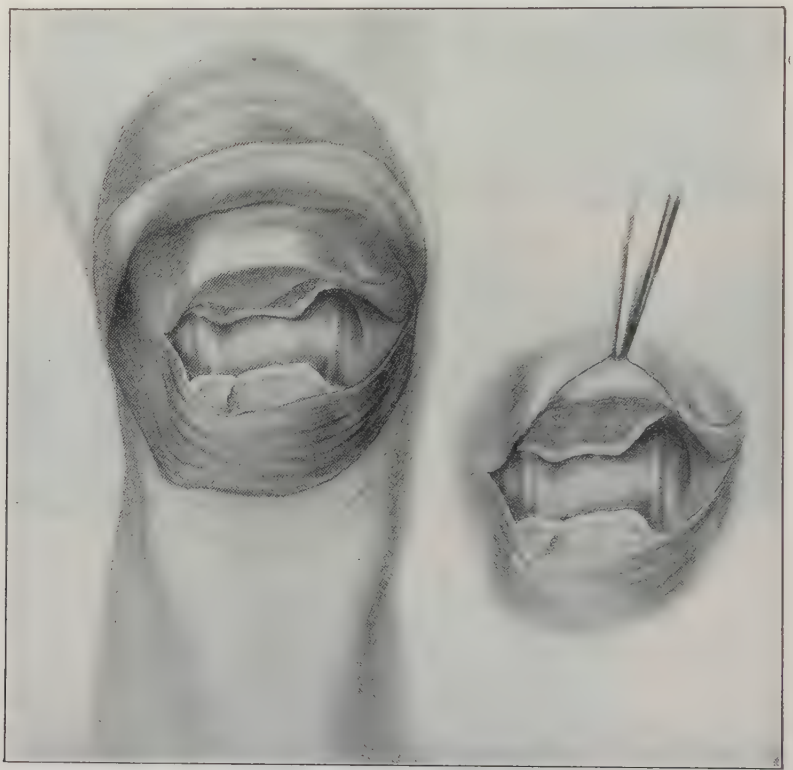


Fig. 1160.—Fracture of the patella, showing fascia lying over broken surface. Smaller figure shows one portion of fascia picked up in forceps.

useful limb. A patella once fractured and having united by fibrous or bony union may be broken through the callus of the healed fracture or in an entirely different fracture from the first break.

Results After Fracture of the Patella.—In a first series of 47 cases of fracture of the patella treated at the Massachusetts General Hospital, occurring between the ages of eleven and sixty-five years, 4 were over fifty years, 13 were under twenty-five years, 29 were between twenty-five and forty-five years, 1 was forty-seven years old; practically, a young adult series. Of this series of 47 cases, 10 were treated by operation and the remainder by the expectant method. These cases are not mentioned in this connection

to compare methods of treatment, but to determine the condition of the knee a long time after the injury. As a matter of fact, in this first series there appeared no greater freedom from the symptoms complained of among the cases operated on than among those unoperated. The results, as carefully recorded in these 47 cases, suggest some of the difficulties that patients experience after fracture of the patella. The detailed reports of these cases, from one and a half to ten and a half years after treatment ceased, show that about 20 have as good a leg as before the accident.

The remaining 27 cases complain of limitation of motion at the knee-joint, that the knee creaks in walking, that it feels stiff, aches and burns at times. The leg is said to be weak, and is troublesome in going up and

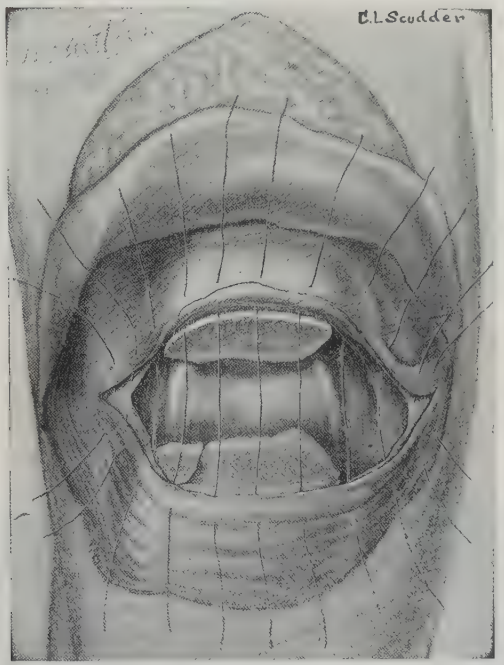


Fig. 1161.—Note the sutures carried through the fasciæ torn about knee in fracture of patella. None of the sutures enter the knee-joint. This method of suture is efficient in approximating most fractured patellæ.

down stairs—stepping up is especially difficult; kneeling is painful; stepping upon irregular surfaces is painful; running with the same freedom as before the accident is impossible; the knee often gives way in walking and causes a fall; the patient cannot jump as before the accident, and walks with a slight limp. Pain is present in or about the knee in damp weather and after unusual exertion. This first series represents the results of treatment before early active movement was used. The complaints of the slightly handicapped have been very explicitly set down.

In a second series of cases of fracture of the patella treated at the Massachusetts General Hospital the end-results have been studied by Quinby and are suggestive. Thirty cases were examined. Of these 30 cases, 24 were

sutured and but 6 treated expectantly. Serviceable knees were obtained in 84.5 per cent. of the sutured cases and in 66.5 per cent. of the unsutured cases. Although these groups of cases are small, yet the general impressions de-

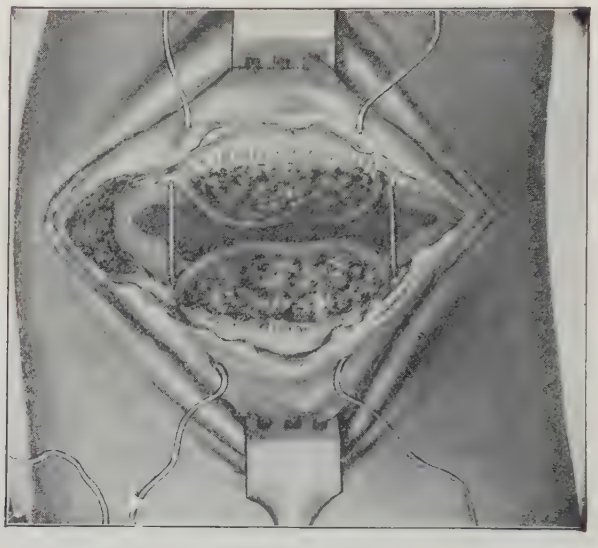


Fig. 1162.—Fracture of patella. Note insertion of sutures so as to avoid joint cavity and yet so as to snug the fragments together when sutures are drawn taut (after Blake).

rived from a study of the individual cases are extremely suggestive, viz., (*a*) certain annoying difficulties persist after treatment by either method, and (*b*) the operative method is to be preferred in selected cases.

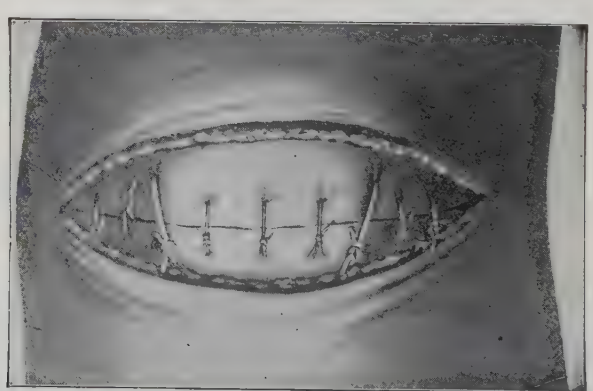


Fig. 1163.—Fracture of patella. Note sutures placed and tied. The skin incision remains to be closed (after Blake).

I believe that the results in this Quinby series is nearer to what may ordinarily be expected. However, 100 per cent. function and solid bony union will be secured in most carefully operated cases today. This is the result to be ideally sought when conditions permit.

Operative Interference in Recent Closed Fractures of the Patella.—*General Considerations.*—In deciding whether a given case should be treated by operation or not, the following considerations should be carefully weighed: A closed fracture of the patella does not in itself endanger life. It may be treated by the conservative method without added risk. If properly treated the result will often be satisfactory as far as the functional usefulness of the knee is concerned. The operative method consumes less time in convalescence and an excellent result is achieved, but operation exposes to the danger of sepsis. If deep sepsis results, the following conditions are imminent: A stiff knee, amputation of the thigh, and possibly death from septic infection. Whether operation shall be done or not, therefore, depends upon the degree of safety with which it can be performed. It is the surest method of securing perfect apposition and bony union. It should be undertaken only by surgeons

Fig. 1164.—Freshly fractured right patella sutured with chromicized catgut. Result after eight weeks. Note flexion of leg to a right angle; line of incision (Warren).

of exceptional judgment and great skill, who have at command skilled assistants, and who can work under the most rigid aseptic conditions. The acute symptoms should be allowed to subside before operation. The tissues require time to recover from the acute trauma.

The operative treatment should be confined to healthy individuals under sixty years of age; to fractures with a distinct separation of the bony fragments and extensive lateral fascial tears (the fascial tears may be recognized by joint distention, localized bulging, and the extent of the separation of the fragments); to cases presenting great joint distention that does not disappear quickly. It should be seriously considered if the individual's occupation is arduous and necessitates much standing or walking. The patient should be informed as to the probable outcome by the two methods of treatment. The danger to life and limb should be fairly stated. It should

Fig. 1165.—Fracture of the lower third of the patella, treated by *absorbable suture*. Note bony union, also slight irregularity of joint surface of patella. Result functionally satisfactory.

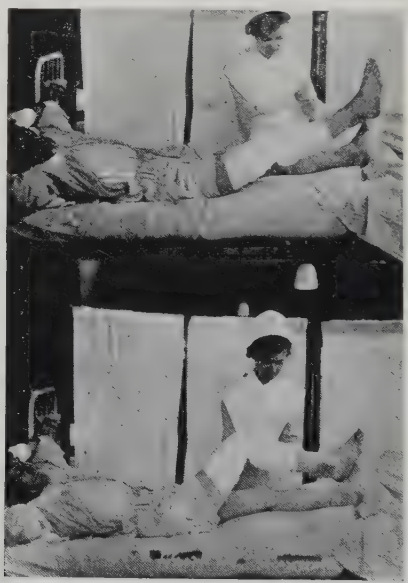


Fig. 1166.—Showing gravity free active motion on the fourth day after operation for fracture of patella. Weight of limbs supported, so that active motion is limited to the joint movements only. Gentle passive assistance to active movement of this joint is given. Note skilled masseuse on this job. (Hawley's case.)

be remembered that the power of extension of the leg is not materially limited by a transverse fracture of the patella in which the tearing of the lateral

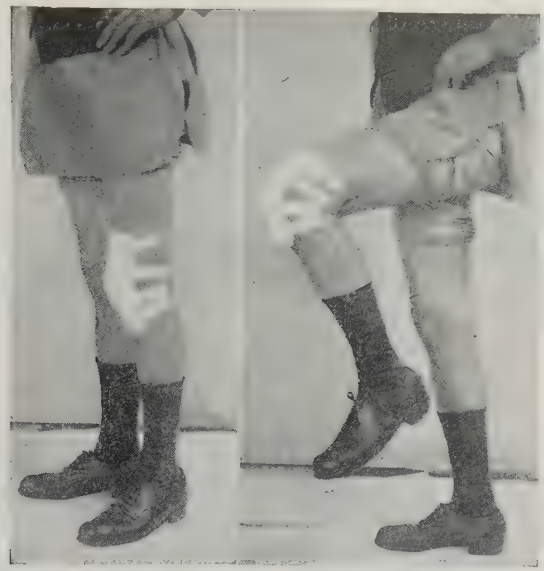


Fig. 1167.—Showing active motion on eighth day. At no time is the effort made to force the range of motion. Patient cautioned to keep within the easy voluntary limitations. Flexion in the upright position carried out at first with the foot parallel to opposite leg, until motor power sufficient to copy high-stepping knee action of the horse. (Hawley's patient.)

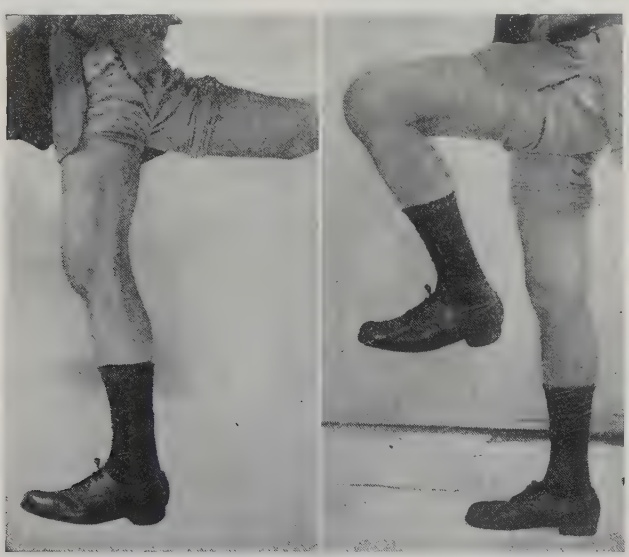


Fig. 1168.—Showing motion at end of fourth week. In this case apparently full functioned recovery in four weeks, and man of his own accord returned to factory work. (Hawley's patient.)

fascia is absent. Only in direct proportion to the extent of the lateral fascial tear is there limitation of the power of extending the leg upon the thigh. In open fractures, in refracture, and in cases of impaired function from long fibrous union or from adhesions of the patella or from badly united patellæ mechanically impeding the movements of the joint, operation is almost always

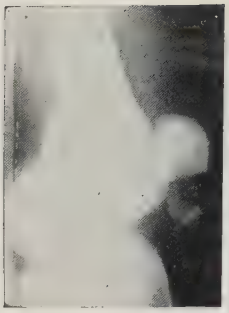


Fig 1169.—Fracture by indirect violence. *x* Ray immediately after the injury. (Hawley's case.)

Fig. 1170.—*x*-Ray seven days after operation. Knee extended. (Hawley's case.)

Fig. 1171.—*x*-Ray seven days after operation. Knee flexed. (Hawley's case.)

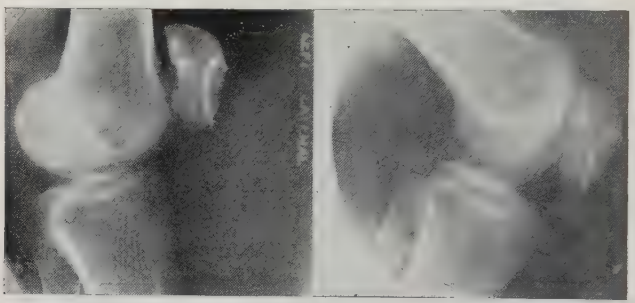


Fig. 1172.—Five months after operation. Showing knee extended and flexed. Slight irregularity of posterior surface of patella not interfering with motion. (Hawley's case.)

Fig. 1173.—Old fracture of the right patella. Note the retracted position of the upper fragment of the right patella.

indicated. The working-man who wants to get to work should, under the conditions previously stated, have his patella sutured, for he will go to work quicker and have a better knee-joint than by any other method of treatment (p. 863).

CHAPTER XVIII

FRACTURES OF THE LEG

Anatomy—Fractures by torsion—Injury to tibial tubercle—Examination—Principles underlying treatment—Treatment—Simple fractures—Immediate reduction—Plaster-of-Paris splint—Temporary dressing—Simple fractures with marked displacement—Plaster of Paris with traction—Wilson-Cochrane method—Nail through os calcis, Thomas splint—Delbet's plaster-of-Paris apparatus—Operative treatment of fracture of the shaft—Fracture of the tibia entering the knee-joint—Open compound fracture of leg—Convalescent care of fracture of leg—The prognosis—Summary of treatment of fracture of tibia and fibula—Fracture of the ankle-joint—Anatomy—Mechanism of ankle-joint fracture—Causes of ankle-joint fracture—Symptoms—Treatment of cases: With displacement; Without displacement—Stimson plaster of Paris—Posterior wire and side splints—Dupuytren's splint—Delbet's splint—Old fracture of the ankle-joint—Convalescent care of fracture at ankle-joint.

Anatomy.—The following structures may be palpated: The internal and external tuberosities of the tibia, the whole of the external tuberosity being subcutaneous; the broad anterior and inner surface of the tibia, which forms the shin, downward to the internal malleolus; the sharp crest of the tibia throughout its whole length; the head of the fibula one inch below the top of the tibia; a little of the shaft of the fibula below the head and the attachment of the biceps tendon; the lower third of the fibula which is subcutaneous. The tubercle of the tibia is distinctly felt on the anterior surface of the upper end of the tibia. It is one inch from the articular surface, and marks the lowest limit of the upper epiphysis of the tibia. Into it is inserted the patellar tendon. The shaft of the tibia arches slightly forward. The shaft of the fibula arches slightly backward. The broad inner malleolus is higher than the outer malleolus, and more to the front of the leg. The outer malleolus is narrow. The posterior edges of the two malleoli are in about the same plane. The anterior edge of the external malleolus is about one inch behind the anterior edge of the internal mallelous. The narrowest part and the weakest place in the tibia is at the junction of the lower and middle thirds of the bone. In the normal leg the middle of the patella, the tendon of the patella, and the midpoint of the ankle are in the same straight line (Fig. 1174).

General Observations.—Fractures of the tibia and fibula may occur at any point, depending upon the seat and direction of the fracturing force. If the force is indirect, the fracture of the two bones will be at different levels. If the fracture is high up, the knee-joint may be involved or the popliteal vessels and peroneal nerve may be implicated. If the fracture is low down, the ankle-joint may be involved. The high fracture of the tibia is usually transverse. The low fracture of the tibia is usually oblique. The common seat of fracture is at about the junction of the middle and lower

thirds of the leg. The line of the fracture is an oblique one, extending from above and behind downward and forward through the tibia. The fibula is fractured a little higher than the tibia. If the force is considerable and the sharpness of the fragments great, the overlying skin may be lacerated, an open or infected fracture resulting from within out (Fig. 1243). The upper and lower epiphyses of the tibia may be separated; these are, however, rare injuries. The tibia and fibula may be fractured separately. In such cases the unbroken bone serves as a splint for the fractured one. The displacement in these latter fractures is slight.

Fig. 1174.—Middle of the patella, tubercle of the tibia, and midpoint between the malleoli all lie in the same straight line as the leg rests naturally.

Fig. 1175.—Fracture of the tibia, low down (Warren Museum specimen).

Fractures by Torsion.—In the long bones the effects of tortion are seen in the shafts of the humerus, femur, and tibia. Torsional force may act on a bone in two ways.

Consider the leg for instance: The body and leg are fixed; the foot is everted or twisted outward, the twisting force is applied at the periphery; the foot is fixed; the body is twisted, the torsional force is applied at the proximal part.

Mechanically the effect on the tibia is to produce a spiral fracture of the shaft. Whether the fibula is broken will depend on its elasticity. Similarly, a spiral fracture may be located in the shaft of the humerus or the femur.

The most common seats of spiral fracture are, in the order of frequency, the tibia, the femur, and the humerus. Spiral fractures and most oblique fractures are spiral, are rather common. Added to the force of torsion is the thrust of gravity (weight of the body) and the bending associated with the loss of bony support.

Usually the spirals in the young bone are longer than in the adult bone, becoming almost longitudinal fractures. The pointer ends of the two long

Fig. 1176.—Fracture of both bones of the leg, high up (Warren Museum specimen).

Fig. 1177.—Old fracture of tibia. Union in malposition; section of bone showing relative position of fragments at seat of union (Warren Museum specimen).

fragments of a spiral are on the same side of the bone and on the tibia, usually posterior. Rixford has directed attention especially to this fracture.

The practical importance of these torsion fractures lies in the following facts:

1. The results of treating spiral fractures are unsatisfactory because they *are* spiral.

2. Non-union is frequent in spiral fractures of the tibia.

3. Irregularity of the bone following union and a symptom-producing external rotatory deformity follows in most cases.

4. There is also seen an abduction of the lower leg on the upper femur which increases the tendency to a pronated foot.

5. The sharp points and knife-like edges of spiral fracture fragments may lacerate muscles, nerves, blood-vessels, penetrate intermuscular septa, and adjacent or overlying skin, making the fracture an open one.

6. If there is any displacement in these fractures unrelieved, unreduced, especially a rotatory displacement, there is a very considerable deformity clinically.

7. The short periosteal bridge between fragments prevents the correction of the external rotation.

8. A dead space almost always exists in the spiral fracture, lined on one side by connective tissue, shreds of periosteum (outer surface of the periosteum), which may grow into it more rapidly than bone tissue may form, and hence tend toward non-union (compare soft tissues between patella fragments).

Consequently, torsion fractures are deserving special attention on the part of the surgeon from the point of view of treatment. It is a common fracture. It occurs in the tibia most usually. It is difficult to replace. Accurate reposition is desirable. If not accurately replaced, late deformities and difficulties due to lack of alignment will arise, the fracture is likely to be an open one. The nutrient tibial artery may be ruptured, adhesions of muscle and tendons to the bone may take place. Circulatory disturbances causing edema of the ankle and leg may appear. Delayed union, fibrous union, or even non-union may result.

Because of the above possibilities it behooves the surgeon to recognize this fracture wherever it occurs, in tibia, in femur, or in humerus, and, having recognized it, to treat it immediately effectively.

The direct operative treatment will probably yield the best and most satisfactory functional results. The reason for operating will be that ordinarily simple traction will not correct the fracture, neither will torsion nor eversion or inversion of the distal fragment, nor will lateral pressure alone. It is in a combination of these three forces that success in replacement lies. I believe that direct treatment is the simplest and most efficient.

It is a fracture in which contentment with simple satisfactory longitudinal alignment does not seem to be wise.

It should be possible in most oblique fractures to determine before treatment is begun whether the chances for union without deformity are better with or without an open operation.

INJURY TO THE TIBIAL TUBERCLE

The beak-shaped process of the tibia probably has its own bony nucleus appearing at eleven years. This nucleus merges at fifteen years with the upper tibial epiphysis.

It is not very unusual in young athletic adults to find a starting of the upper epiphysis of the tibia as illustrated in Fig. 1178. It has been demonstrated recently that many apparently trivial injuries, such as violent contraction of the quadriceps extensor muscle, a blow to the region of the tubercle of the tibia, result in partial separations, with or without some displacement of the tongue-shaped portion of the upper epiphysis of the tibia, or actual separation of an independent bony center for the tubercle of the tibia. The trauma necessary to produce this lesion may, therefore, be either

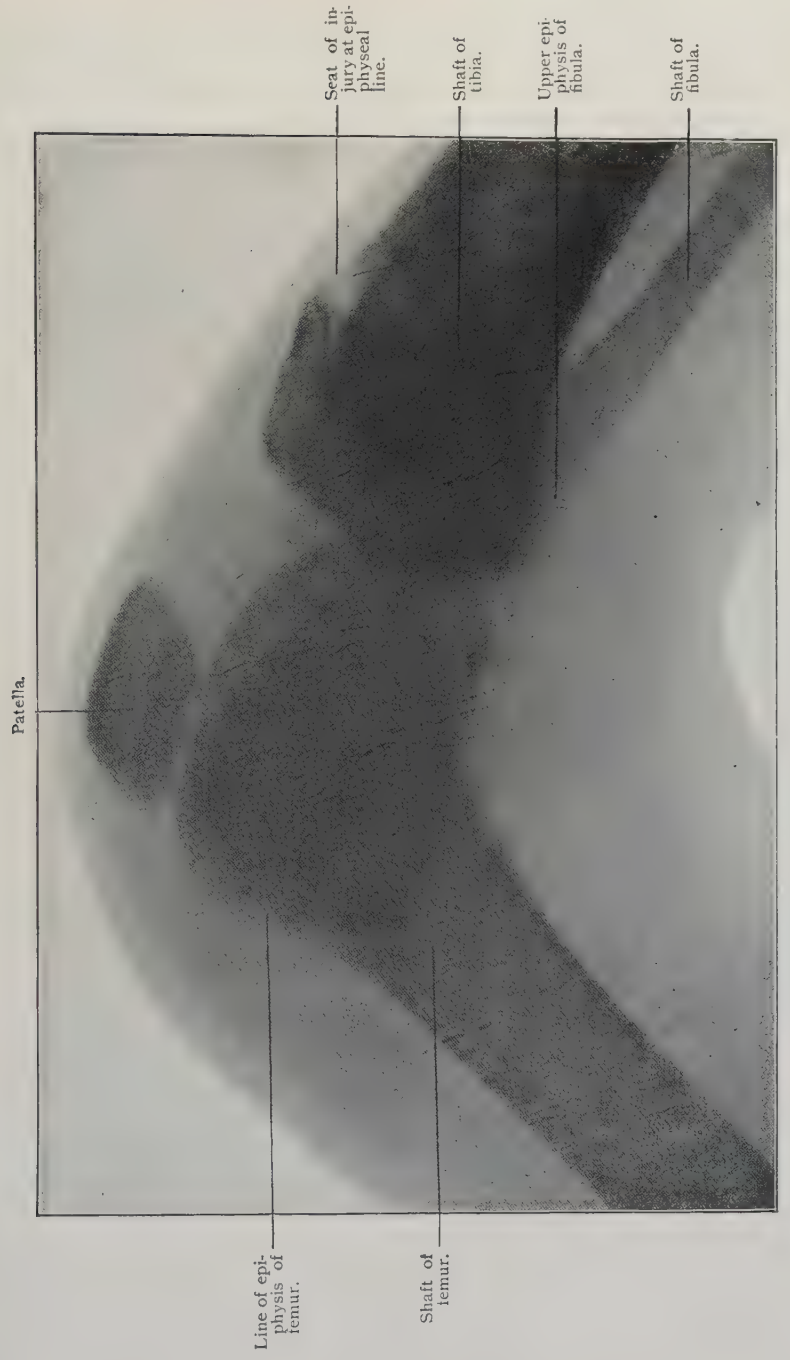


Fig. 1178.—Injury to knee. Note starting of upper epiphysis of the tibia.

direct or indirect. In youth, before sixteen years of age, injury to this part results in a starting of this epiphysis, while injury in adult life is more likely to cause a fracture of the tongue-like portion of the epiphysis. Clinically,

slight swelling and tenderness in the region of the tibial tubercle and pain upon extension are the chief signs. The term "starting of the epiphysis" is used advisedly. There may occur a literal starting or beginning separation of the epiphysis which will show in the Roentgen ray as a slightly wider spacing of the epiphysis from the diaphysis. The symptom of tenderness points in such cases to the exact line of the epiphysis.

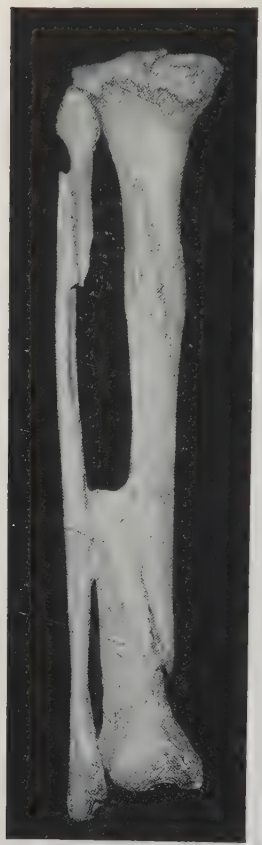


Fig. 1179.—Fracture of both bones of the leg; displacement of upper fragments downward and inward; union (Warren Museum, Specimen 8303).

If the local symptoms following an injury to the tibial tubercle do not disappear under appropriate treatment, or if the difficulty goes untreated, the condition may be thought to be a tumor of some kind, a bursitis, localized tuberculosis, an epiphysitis, or a traumatic periostitis.

Osgood believes that at the time of the injury there is felt acute pain in the knee referred to below the patella. There is often slight swelling, either general or pretty definitely localized over the region of the tubercle. There is distinct tenderness at this point. The ability to use the leg is only slightly diminished, and the acute pain is soon replaced by a feeling of weakness on strong exertion. Sharp pain is present on violent extension or extreme flexion of the leg, and the patient usually consults the surgeon because of this pain, the annoying weakness, and the continued localized swelling or tenderness.

The condition presents no complete loss of function, but a severe handicap to the active, athletic life which this class of patients wishes to lead.

Complete or partial immobilization of the knee-joint upon the injured side for a longer or shorter time will ordinarily suffice to effect a cure of the difficulty. If protective methods fail after fair trial, operative pegging or removal of the fragments is to be considered. The outlook for these cases in general is excellent. Recovery usually follows promptly after appropriate treatment is instituted.

Jones has suggested a linear incision with a narrow chisel into the tubercle in the longitudinal axis in order to stimulate the reparative process which will assist in a cure of a thickened and tender tubercle.

Fracture of the Tibial Spine.—This fracture occurs most often as a complication of dislocation of the knee or of a fracture of the tuberosity of the tibia, the lateral mass of the tibia.

It occurs as an uncomplicated fracture and should be so recognized.[1]

[1] Frank E. Blaisdell, Sr., M. D., Archives of Surgery, 5, 1922, p. 561.

Anatomy.—The knee-joint is superficial. Its strength is bony, ligamentous, fascial, and muscular.

The bones entering the joint are large. The anterior and posterior crucial ligaments are attached in front of and behind the tibial spine. The fascia lata strengthens the joint laterally, and the tendon of the quadriceps steadies the joint anteriorly.

The ligamentous structures about the knee-joint are very strong. Extension of the knee is limited by the crucial ligaments, flexion is limited by the ligamentum patellæ and the anterior part of the capsule together with the crucial ligaments.

Rotation of the knee is possible only when the knee is flexed. When the knee is flexed it is in a very vulnerable position.

The factors rendering the tibial spine of the knee-joint liable to injury are numerous and variable. The protecting agencies of the knee may be so disarranged or thrown off their guard that a very slight force may cause a fracture of the spine of the tibia.

A strain is a stretching of the soft parts with a minimum damage. It is not macroscopically recognizable.

A sprain is a rupture of soft parts (ligaments, fasciæ) recognizable by ecchymosis, loss of function, and pain.

A sprain fracture is recognizable in its mild form by Roentgen-ray examination only.

Injury to the knee will result in a rupture of the crucial ligament or ligaments, a fracture of the tibial spine, or even a fracture of the femoral condyle (Blaisdell's "crucial triad").

When the tibia cannot be displaced forward in the extended position, it may be assumed that the anterior crucial ligament is not ruptured. If the tibia cannot be displaced backward when the knee is in full flexion the posterior crucial ligament is intact (Robert Jones).

Injuries to the knee which appear trivial may be accompanied occasionally by the crucial triad lesions.

Sprain fracture of the knee-joint may be present without signs other than the Roentgen-ray evidence.

Blows on the front of the thigh above the knee and on the posterior surface of the leg over the tibial head and forcible external and internal rotation or twisting of the leg—all of these forms of force are competent to produce the "crucial triad" of lesions which includes a fracture of the tibial spine.

In no fracture perhaps is the disturbance of the balance of the various factors entering the protective mechanism of the joint so difficult of measurement as in this fracture of the spine of the tibia.

Treatment will be adapted to associated injuries about the knee, but rest, freedom from weight bearing for a limited time, with gradual re-establishment of movement of the knee and locomotion, will be desirable.

Examination of a Fractured Leg.—It is sometimes extremely difficult to detect a fracture of the leg. It is, therefore, important that a systematic examination should be made immediately after the injury. An open fracture

will be evident if a wound exists in the skin near the seat of fracture. Deformity will ordinarily be apparent upon inspection (Fig. 1182).

A Roentgen-ray examination in the anteroposterior and the lateral planes should be made as soon after the injury as possible.

Gentle manipulation will suffice to satisfy one of the existence of a fracture, particularly if both bones are broken. In taking hold of the leg for examination or for moving the leg it should not be grasped lightly by a few fingers, but by the whole hand, firmly, as one grasps an ax-handle in chopping wood; not as one lifts a lead pencil from the table. The leg should be so raised in making the examination that there is absolutely no risk of converting the closed fracture into an open one. In order to guard against this the assistant should grasp the foot at the ankle and make gentle but strong traction in the long axis of the leg as the whole leg is raised. This care in examination will cause the patient a minimum amount of pain.

Fig. 1180.—Method of measuring the length of the tibia from the internal tuberosity to the internal malleolus.

Crepitus is not the only thing that is to be sought at the examination. The freedom of any abnormal mobility should be noticed, as well as the direction of the motion, the ease with which reduction is possible, and the liability to recurrence of the deformity.

While an assistant steadies the knee-joint the surgeon, grasping the lower part of the leg, attempts motion in each direction. Simply raising the leg and attempting motion in an anteroposterior direction is not sufficient; a fracture of the tibia, if transverse, might remain completely locked except upon lateral movement. The bones should be palpated.

A definite point and line of local tenderness upon even deep palpation over the subcutaneous surfaces of the tibia and fibula will be indicative of a linear fracture.

The tibia should be measured (Fig. 1180) from the knee-joint line, at the upper border of the internal tuberosity, to the lower edge of the internal malleolus to determine shortening. Shortening of the leg may be roughly

estimated after union of the bones by comparing the height of the two knees while the soles of the feet rest upon the floor (Fig. 1181). The measurement

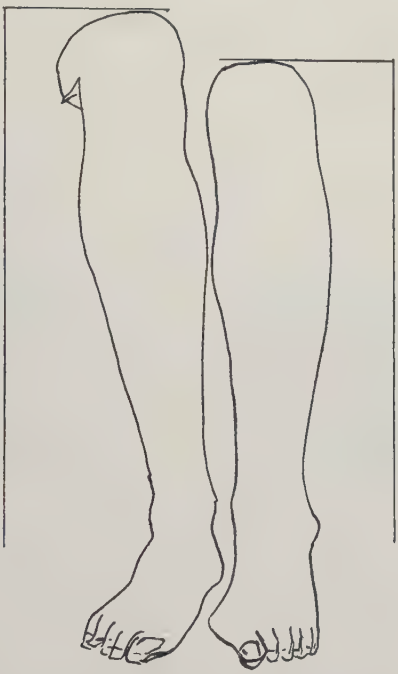


Fig. 1181.—Fracture of both bones of the left leg. Comparative height of knees to show shortening of leg. The patient is sitting with knees flexed to a right angle (after Van Lennep).

should be compared with that of the uninjured tibia. It is often difficult in fractures near the ankle to palpate the internal malleolus on account of swelling. Deep pressure with the thumb will detect it. Inquiry should be

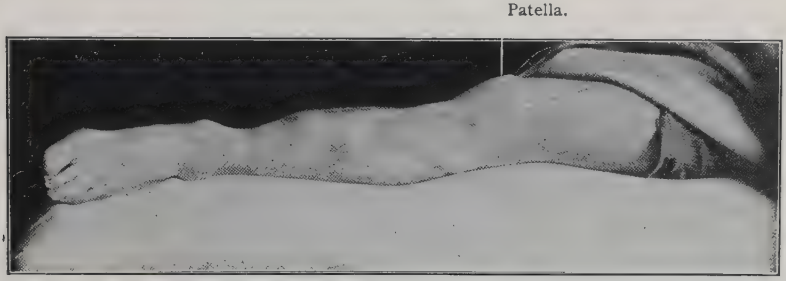


Fig. 1182.—Fresh fracture of the leg (both bones). Characteristic deformity Note normal position of patella, with the foot lying on its outer side. Prominence of upper fragment. Compare this with Fig. 959 of a fracture of the thigh in which the patella does not look upward.

made as to whether either tibia has ever been fractured previously. The pulse should be felt for in the posterior tibial and dorsalis pedis arteries to be sure that the large vessels of the leg are intact.

Symptoms.—Ordinarily, the presence of pain, deformity, abnormal mobility, crepitus, local tenderness, and loss of use of the leg will be the evidences of fracture. If the fracture is of the tibia or fibula alone, and transverse without much displacement, localized tenderness upon pressure and swelling will be the only signs. The sign of local point pressure tenderness in any fracture may be an important sign. If this sign is present unmistakably it will be unnecessary to find other signs to make the diagnosis of

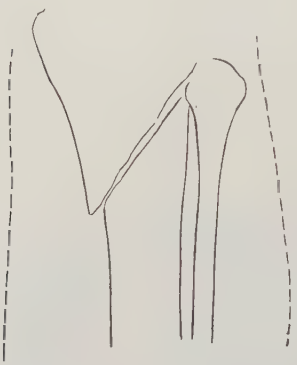


Fig. 1183.—Fracture of the tibia, oblique and high up. Almost no displacement (Massachusetts General Hospital, 1235. *x*-Ray tracing).

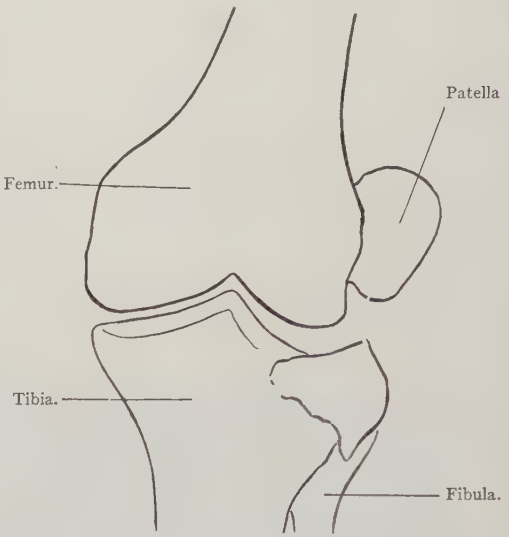


Fig. 1184.—Fracture of the external tuberosity of the tibia (Massachusetts General Hospital, 1242. *x*-Ray tracing).

Fig. 1185.—Longitudinal fissuring of tibia from blasting accident. Front view (*x*-ray tracing).

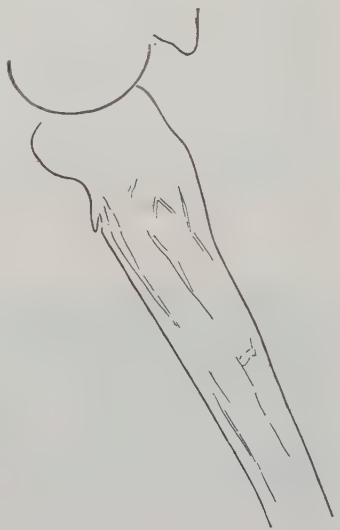


Fig. 1186.—Longitudinal fissuring of tibia from blasting accident. Lateral view. Same as Fig. 1185 (*x*-ray tracing).

fracture. It is important to remember the normal backward bowing of the fibula in attempting to localize by palpation the tender point of the fracture of that bone.

The *deformity* is due to the displacement of the upper fragment forward and of the lower fragment upward and backward. If the fracture is oblique, this displacement will be considerable. The lower fragment is often rotated upon its longitudinal axis, so that the foot rests upon its side,

Fig. 1187.—High fracture of both bones of the leg.

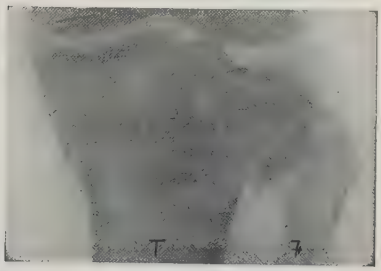


Fig. 1188.—High fracture of tibia and fibula, antero-posterior view. See Fig. 1189.

while the upper fragment remains undisturbed by rotation, the patella looking directly upward (Fig. 1182).

The amount of *swelling* of the leg will vary. It may be extremely slight and limited to the seat of the fracture or it may extend over the entire leg.

Fig. 1189.—Same as Fig. 1188, lateral view.

The maximum swelling of the leg is usually reached three or four days after the accident. If the fracture was caused by direct violence and the fragments of bone are sharp, the soft parts will be damaged and the resulting hemorrhage and swelling will be very considerable.

Ecchymosis of the skin appears in from twenty-four to forty-eight hours after the accident; it may extend over the whole leg. Ecchymosis from a sprain is localized more or less about the seat of the sprain; that from a fracture is often extensive. *Blebs* or vesicles may appear near the fracture during the first week if the swelling is great. It is necessary to exercise great caution in the care of these blebs, that they do not become infected. An infected bleb may involve so large a surface and extend to the thigh deeply, invading so many planes of muscle, eventually causing an infection of the

Fig. 1190.

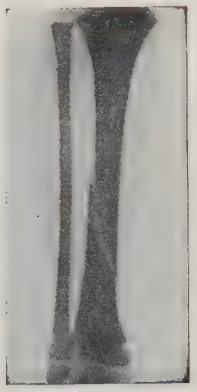


Fig. 1191.

Fig. 1192.

Fig. 1193.

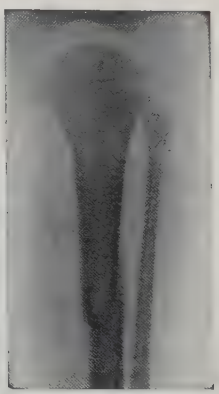


Fig. 1194.

Figs. 1190–1194.—Types of fracture of the tibial shaft.

knee-joint, that the life of the individual may be concerned and amputation result, perhaps, in a vain attempt to save the patient's life.

Fracture of the shaft of the fibula alone may be very obscure. Pressure upon the fibula toward the tibia will elicit pain and crepitus if there is a fracture in the shaft protected by muscle masses. Pressure upon the fibula directly wherever it is subcutaneous will elicit tenderness if there is a fracture at the point palpated. In separation of the lower epiphysis of the tibia the preservation of the normal relations between the malleoli is of considerable diagnostic importance.

Fig. 1195.

Fig. 1196.

Fig. 1197.—Note changes in distal fragment.

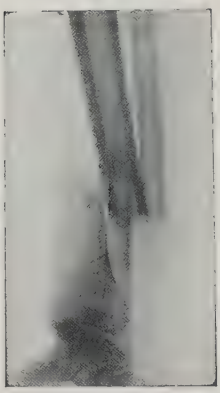


Fig. 1198.—Note light shadow of distal fragment of tibia.

Figs. 1195–1198.—Types of fracture of the tibia and fibula.

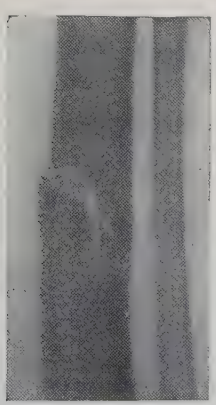


Fig. 1199.—Fracture of tibia, subperiosteal. Rather rare.

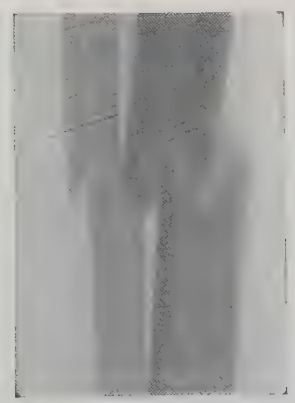


Fig. 1200.—Anteroposterior view. Both bones fractured near the middle. Considerable displacement of tibial fragments. A longitudinal split seen in the fibula.

Principles Underlying the Treatment of Fractures of the Tibia and Fibula.—In no other part of the body is a long bone limited by joints having only hinge-like motion. The knee- and ankle-joints flex and extend essentially in the same anteroposterior plane. Consequently, any deviation from the normal anatomic relationship is very important. The demand for an exact anatomic reposition of fragments is imperative. Painless and untroubled weight bearing is dependent on the normal ankle mortise. The tibio-astragaloid joint should receive the weight thrust in normal lines.

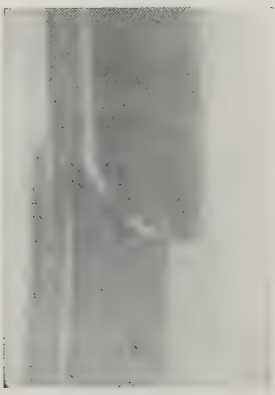


Fig. 1201.—Anteroposterior view. Both bones fractured at middle. Slight displacement, little comminution. Important in this fracture to avoid a bending backward or forward at the seat of fracture.

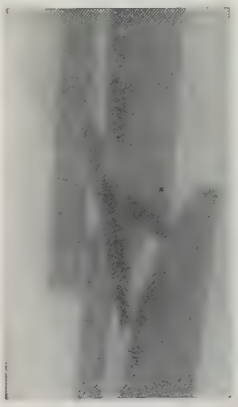


Fig. 1202.—Anteroposterior view. Both bones fractured near the middle. Much displacement laterally and longitudinally. Comminution of tibia, one large fragment seen. Open incision indicated in such a fracture.

A plane which bisects the long axis of the tibia should normally bisect the astragalus (Skinner).

Angulation of the tibial shaft will, therefore, interfere with weight bearing.

In treating fractures of the shafts of the tibia and fibula, therefore, the securing of a perfect alignment of fragments should be the fundamental principle.

Exact length of the leg is desirable, but not absolutely essential. Perfect function of the leg is most likely if a perfect anatomic reposition is secured at as early a date as possible.

Rotation of either fragment upon its long axis is to be avoided; the foot is to be kept extended to a right angle with the leg; lateral deviation of fragments must not be tolerated; the inner side of the great toe, the middle of the patella, and the anterior superior spine of the ilium should be in one straight line; anteroposterior bending with the convexity backward is to be prevented (Figs. 1219, 1220). Roentgen-ray records of the fracture should be had often enough to keep the surgeon informed as to the exact position of the fragments.

THE OPERATIVE VERSUS THE NON-OPERATIVE TREATMENT OF FRACTURES OF THE LEG

It must be constantly borne in mind that in order to secure a normal leg functionally an exact alignment is necessary and as nearly normal length as is possible.

Most simple closed fractures will be satisfactorily treated by a closed method. If after seven days' trial the closed method is ineffective, operation should be done.

In fractures of the tibia entering the knee-joint displacement of articular fragments should be directly replaced and fixed.

In fractures of the tibia entering the ankle-joint displacement of articular fragments not accurately replacable by position should be directly replaced and fixed by operation.

In certain oblique spiral shaft fractures of the middle and lower thirds in which it is established that great difficulty attends traction, reposition should be immediately done by operation.

In almost all instances in which a primary operation reduction is to be done a preparatory delay of seven days is desirable.

In certain open or compound fractures of the leg direct immobilization of the fracture is indicated and desirable when the wound is sterile.

Non-operative Treatment.—For purposes of discussing treatment, fractures of the leg are arranged into several groups, viz.:

1. Fractures with little or no swelling or displacement.
2. Fractures with considerable swelling.
3. Fractures with a displacement of fragments difficult to hold corrected.
4. Open fractures.

The indications to be met by treatment in each of these groups are: care of the soft parts, including the open wound, correction of the deformity, immobilization of the fragments, and restoration of the limb to its normal condition.

Simple Fractures with Little or No Displacement or Swelling.—On admission to the hospital or home the leg should be temporarily supported in a pillow splint. An immediate Roentgen ray should be had. Fractures of the tibia alone or the fibula alone are properly placed in this group. Fractures of both bones occasionally occur with little or no displacement and with but a trifling amount of swelling. In these cases the leg should be elevated for ten minutes in order to lessen the swelling. The foot, leg, and lower thigh are then bathed with soap and water, and thoroughly dried and powdered. It will be wise to shave the leg.

Infection may arise from neglect in caring for the whole skin surface of the damaged part. Unsuspected abrasions will be disclosed which might be the openings for infection. The leg being properly protected, a light plaster-of-Paris roller bandage is applied from the toes to the middle of the thigh. (See Details of Plaster Work.) The leg is to be kept elevated for the first week by at least two or three pillows. If good judgment is exercised in the

Fig. 1203.

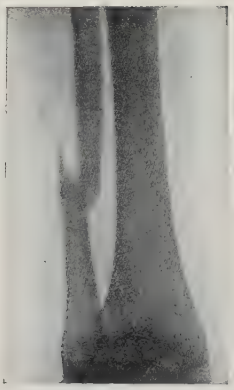


Fig. 1204.

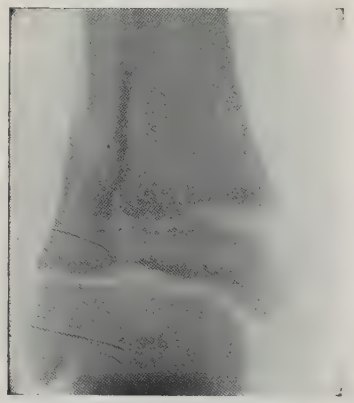


Fig. 1205.

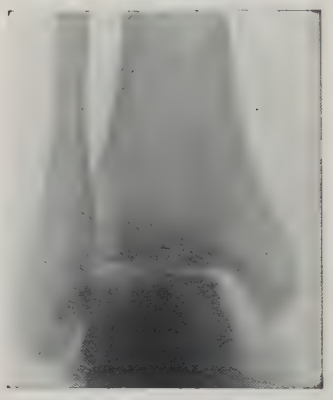


Fig. 1206.

Figs. 1203–1206.—Fracture of the fibula. Types of fracture.

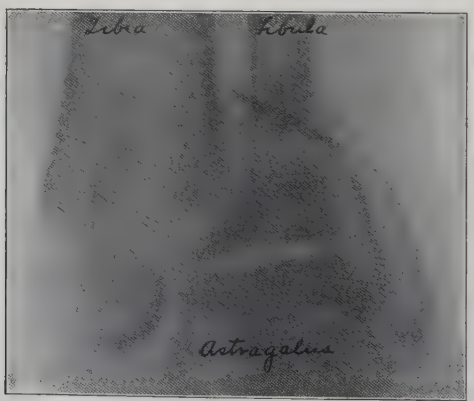


Fig. 1207.—Transverse fracture of both bones of the leg close above the ankle-joint. Displacement of the foot outward.

subsequent care of the case, the placing of such a fracture, as previously indicated, immediately in a plaster-of-Paris splint is attended by no risk. The danger lies in too great pressure upon the circulation caused by the increasing swelling of the leg within the unyielding plaster splint. Pressure

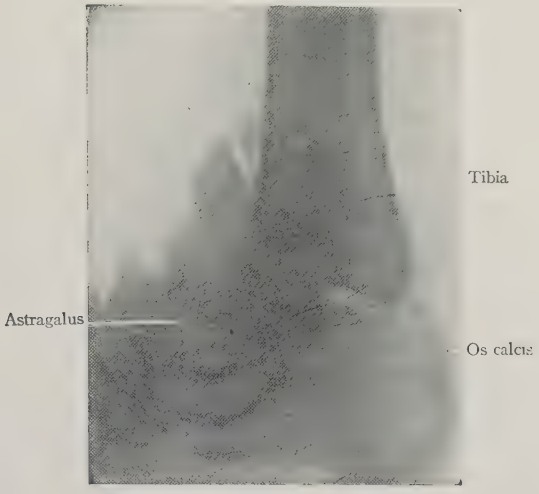


Fig. 1208.—Type of fracture near ankle-joint.

sores and gangrene are liable to result. In applying the splint a liberal amount of sheet wadding should be used. The condition of the circulation should be noted immediately after the application of the splint and at regular intervals thereafter until all danger from undue pressure has ceased. Evi-

Fig. 1209.—Type of fracture near ankle-joint.

Fig. 1210.—Type of fracture near ankle.

dences of too great pressure are persistent or increasing swelling of the toes, blueness of the toes, and pain.

The Cutting of the Plaster Splint.—It is well always to split the plaster the entire length of the splint before it has quite hardened. The cutting of

the plaster should be done in one of three ways, according to the line of fracture and probable direction of its displacement.

The cutting of the plaster is done in a median line, anteriorly and posteriorly, thus providing two lateral plaster splints.

The cutting of the plaster is done in two lateral lines (the usual method), thus providing an upper anterior and a lower posterior splint. The cutting of the plaster may be done in the anterior line only, allowing of separation of the cut edges, thus relieving increasing pressure in the circulation of the legs.

This method of immobilizing simple fractures without displacement is easier and simpler than by the use of Stimson's method for the general practitioner who is unskilled in special methods. Stimson's method is equally applicable to the above conditions.

The splint loses by this procedure none of its immobilizing qualities, for it can be bandaged or strapped tightly together again. Too great pressure upon the circulation can then be immediately relieved by loosening the retaining straps or bandage and thus opening the splint. After the splint has been on the leg for about a week and a half or two weeks, the swelling having begun to subside, the plaster splint will become loose and will cease to hold the fragments firmly. Unless a new and snug splint is now applied, it will be necessary to cut out a strip of plaster one inch or more wide from the old splint to admit of tightening. During the changing of the plaster splint the leg should be steadied by an assistant while it is thoroughly washed with soap and water and bathed with alcohol.

Fractures With Considerable Immediate Swelling.—Many fractures are not seen by the surgeon until two or three hours after they have occurred, when considerable swelling is present. Associated with such primary swelling there may be laceration of the soft parts and possible extensive injury to the bone. Blebs filled with clear or bloody serum may be present about the seat of fracture. These should be evacuated after the part has been rendered surgically clean by washing with soap and water and 70 per cent. alcohol, and then dressed with a dry antiseptic powder, powdered dermatol, aristol, or boric acid powder. Infection may take place through blebs. Very great care should be exercised in their treatment. Obviously, it is unwise immediately to apply a plaster-of-Paris splint to cases in which there are many blebs and much swelling.

The swelling of the leg may become so great that the life of the limb may be at stake, the danger from impending gangrene becoming imminent. In such cases the skin of the leg becomes tense and shiny, the leg feels hard and board-like, pain may be extreme, and the toes and foot become slightly blue. The hemorrhage, being confined beneath the fascia and skin, causes pressure upon the circulation. The circulation in the leg is thus impeded. Under such circumstances operation is necessary in order to relieve tension and to check hemorrhage. Incisions in the long axis of the limb through skin and fascia will be followed by a rapid decrease in the swelling of the leg and a cessation of the pain. After incision small bleeding vessels should be ligated. If these wounds remain aseptic, they may be

closed after a few days by suture or may be allowed to heal openly. This method of treatment will usually result in saving the leg (Figs. 1212, 1214). If the circulation does not return and gangrene is imminent, immediate amputation of the limb well above the fracture at the lower or middle third of the thigh is the best procedure. Traumatic gangrene is often

Fig 1211.—Fracture of both bones of the leg from bullet wound. Characteristic comminution of the bones. Bullet not removed. Recovery with a useful leg (*x*-ray tracing) (Warren).

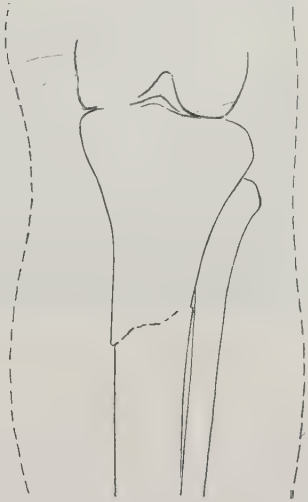


Fig. 1212.—Transverse fracture of the tibia, high. Direct violence. Great swelling of leg. Threatening gangrene. Free incisions. Leg saved. Result good. Same case as Fig. 1214 (Massachusetts General Hospital, 1074. *x*-Ray tracing) (Scudder).

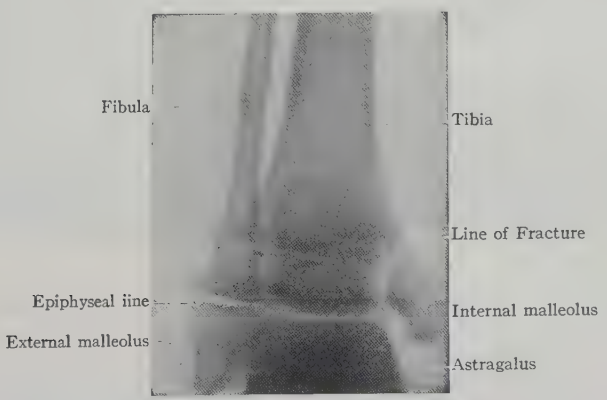


Fig. 1213.—Fracture of the internal malleolus only, *i. e.*, the inner part of the lower epiphysis of the tibia.

rapidly followed by general septic infection. It is best to use a temporary splint in cases in which there is great initial swelling of the leg.

Immediate Reduction of the Fracture.—It is important to know that the policy of waiting for the ordinary swelling to appear and subside after a fracture of the leg and then to attempt reduction is absolutely unwise. The earlier the fracture is reduced, the sooner after the accident the bone fragments are replaced as nearly as possible in their normal relations the better.

Fig. 1214.—Closed fracture of the left tibia. Hematoma. Impairment of the circulation. Free incisions. Evacuation of blood. Relief of pressure. Leg saved. Recovery (Scudder).

It must not be forgotten that the swelling of the leg following a fracture will be in proportion to the time of reduction. If reduced at once the swelling will be at a minimum; if several days elapse before reduction the swelling will be greatest.

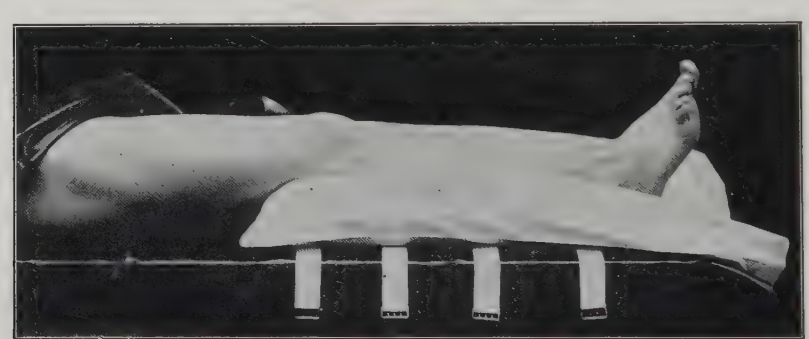


Fig. 1215.—Fracture of the leg. Temporary or emergency dressing. Application of the pillow with straps. Open end of the pillow-case at the foot.

Moreover, the ease with which reduction can be effected is far greater immediately after the injury than at any other time. Swelling prevents extension from being effective. Round-cell infiltration of fascial and connective-tissue planes render the opposition to traction and countertraction very considerable. Muscular contraction and fascial resistance will be harder to overcome after the delay of a few hours or days.

Therefore when practicable an attempt at reduction of the fracture of the leg should be made as soon as possible after the accident.

The Temporary Dressing.—The Pillow and Side Splints: The leg is placed on a pillow covered with a pillow-case; straps are placed under the pillow and drawn snugly up about the leg (Fig. 1215). The edges of the pillow are rolled in against the leg for firmness. Narrowly folded towels are placed between the leg and the straps. The straps are then drawn tighter. The open end of the pillow-case is folded and pinned under the sole of the foot.

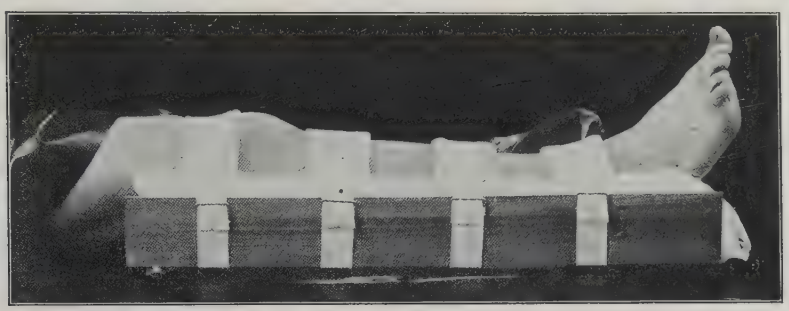


Fig. 1216.—Fracture of the leg. Pillow and side splints with straps and towels. Compare Fig. 1217.

Three pieces of splint wood are introduced between the pillow and straps—one is slipped underneath and one upon each side of the pillow. The pillow thus serves as a padding for the box formed by the splint wood (Fig. 1216). Ice-bags may be conveniently placed along the anterior surface of the leg between the edges of the pillow. They relieve pain and are said to check hemorrhage immediately after the fracture. If greater security is thought necessary, the pillow-case, instead of having its sides rolled in, may be pinned with shield-pins up over the anterior surface of the leg (Fig. 1217).

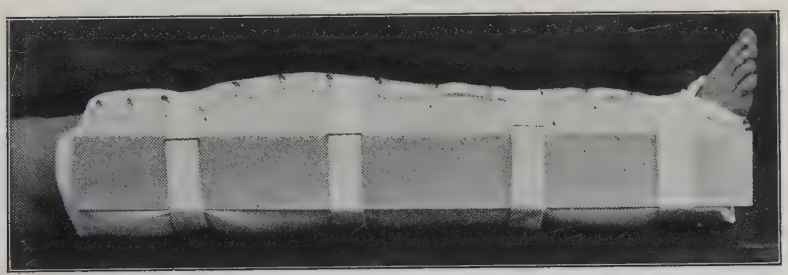


Fig. 1217.—Fracture of the leg. Temporary or emergency dressing. Pillow, side splints, and straps. Pillow held by shield-pins.

With the acceptance of the principle that the *immediate* reduction and immobilization of the fracture of the leg is far easier than a *late* reduction, the use of a temporary dressing is to be made only when the immediate reposition of fragments is unwise or impossible for various reasons.

There are certain fractures of the leg without displacement not requiring reposition which may very properly be placed in a Cabot posterior wire splint (pages 667–669) and then be immediately suspended.

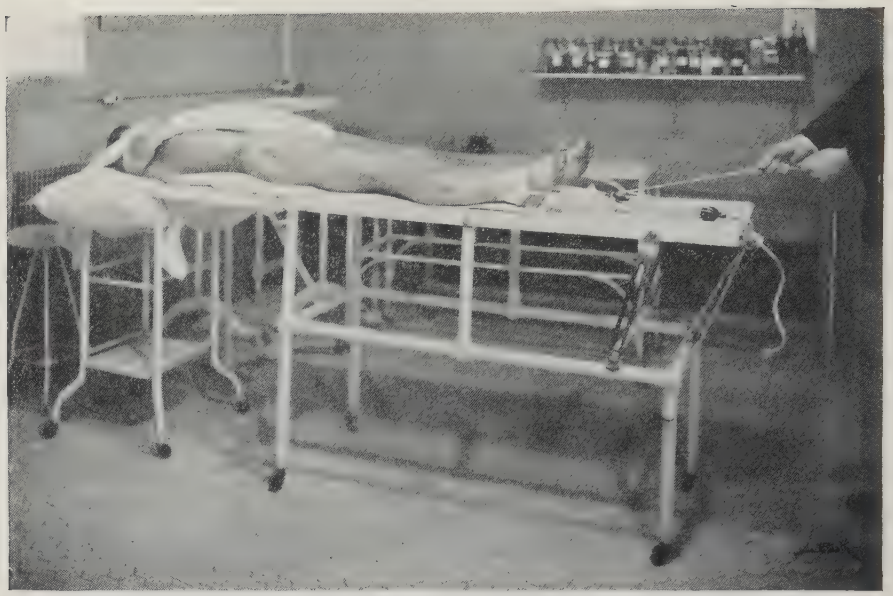


Fig. 1218.—Method of obtaining traction for leg fracture without the use of the Hawley table. Foot is fastened with a clove hitch to one pulley and the other pulley is fastened to the foot of the table. Counter-traction is made by means of a sheet through the thighs and fastened to the head of the table. (From Magnuson and Coulter, in International Clinics, vol. 1, Series 31. J. B. Lippincott Co., Publishers.)

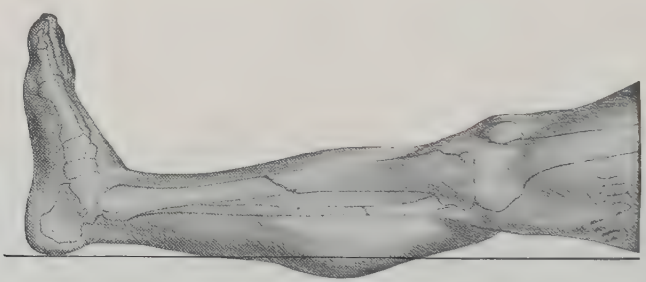


Fig. 1219.—Natural position of leg and bones resting on a posterior splint. Note seats of fracture of tibia and fibula. No displacement indicated.

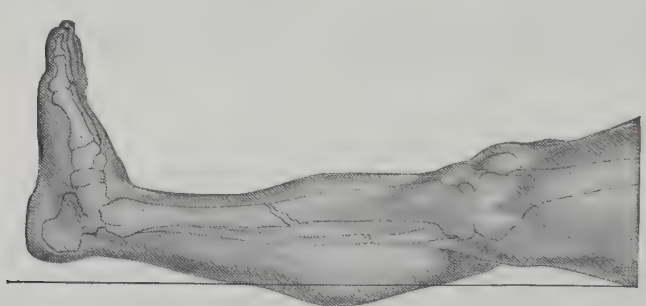


Fig. 1220.—Same as Fig. 1219. Note that lifting foot and distal fragments far forward causes a bowing of leg forward and gaping open posteriorly of the fracture. Cause of permanent deformity.

This temporary dressing is left in place for a week or a week and a half. The swelling will then have partly subsided. If at this time there is little or no swelling and the displacement is slight, a plaster-of-Paris splint may be applied as a permanent dressing. Either the circular plaster may be used or the plaster splint known as Stimson's (p. 707). If the circular plaster splint is used it must invariably be cut as described (p. 1110). If, on the other hand, at the end of a week or a week and a half it is desired to have the fracture open to inspection and more directly accessible and under the eye of the surgeon, then the posterior wire and side splints should be applied.

Fractures of the Leg with Marked Displacement of Fragments Difficult to Hold Reduced.—Certain small closed oblique and spiral fractures of the shafts of the tibia and fibula if seen immediately after the accident may be reduced under a general ether anesthesia by traction and manipulation and be held reduced by a plaster-of-Paris splint. This will be especially true if the manipulations are conducted with the aid of a fluoroscope.

If it is found impossible to control the reduction with the fixed splint, skeletal traction by a pin through the os calcis (p. 224) and suspension of the leg in a Thomas splint may be employed.

Very comminuted shaft fractures will be aligned and the fragments snugged together by such traction.

In certain cases with marked displacement it is evident that attempts at closed reduction will do more damage to the soft parts than will an operation. Moreover, the importance of securing a perfect alignment is so great that I believe operative reposition is indicated.

Perhaps the most difficult of shaft fractures to replace and hold securely is a fracture of both bones in the lower third of the shaft (see Fig. 1231). If skeletal os calcis traction will not do it, a partial tenotomy of the tendo achillis will help. If unsuccessful, open reduction should be used.

In the use of skeletal traction in these lower third fractures slight changes in position will often effect reduction. A slight rotation of the lower fragment on its long axis, brought about by making traction on the pin through the os calcis a little off center one way or the other, will bring the broken surfaces of the oblique fracture into apposition.

Slight lateral pressure exerted through a gauze band about the leg to one or the other upright of the Thomas suspending splint may be of assistance.

In fractures in the upper third of the leg not entering the joint ordinary skin traction or skeletal os calcis traction with flexed knee and Thomas splint suspension will control the situation satisfactorily. Ordinarily, following the use of a fixation plaster-of-Paris splint, either as a primary method of fixation or as a secondary step after the Thomas suspension and os calcis pin have been discarded, following the use of plaster-of-Paris, a walking caliper splint should be used.

The Posterior Wire and Side Splints.—The posterior wire or Cabot splint is made of iron wire the size round of an ordinary lead pencil (Fig. 1221). It is applied to the back of the foot, leg, and thigh, extending from just beyond the tips of the toes to above the

middle of the thigh. It is narrow at the heel and broad enough above to permit the thigh to rest comfortably upon it. The foot-piece is at right angles to the leg.

Fig. 1221.—Padding the Cabot posterior wire splint. Applying sheet wadding. The shape and proportions of the Cabot splint are apparent

Having at hand the iron wire the size of an ordinary lead pencil, this splint can be quickly and easily made by means of a vise for holding the wire, and a wrench for grasping the wire while bending it. The two free ends of the wire of the splint may be held firmly together by having them overlap and binding them together with small-sized copper wire. These free ends may, of course, be held by solder.

The Covering of the Posterior Wire Splint: The wire is wound first with a roller of sheet wadding, then with a cotton roller, and finally a cotton roller bandage is wound about both sides of the splint so as to make a posterior surface upon which the leg may rest (Figs. 1221, 1222, 1226).

Fig. 1222.—Padding the Cabot posterior wire splint: (1) With sheet wadding (see Fig. 1221); (2) with a cotton roller around the wire, and (3) around both wires, to form a back to the splint.

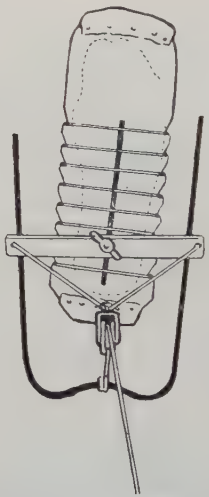


Fig. 1223.—End view of Sinclair "skate" showing possibility of maintaining outward rotation of the foot (Christopher).

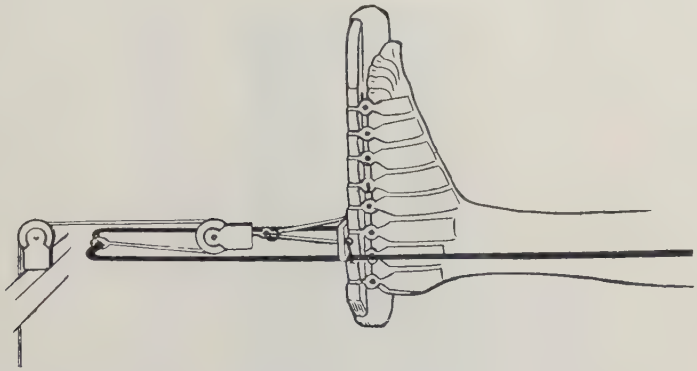


Fig. 1224.—Sinclair "skate." Lateral view of "skate" and pulley. Illustrating method of securing proper amount of dorsal flexion of the foot by adjusting the transverse bar farther up or down the skate. Showing a method of attaching the pulley (Christopher).

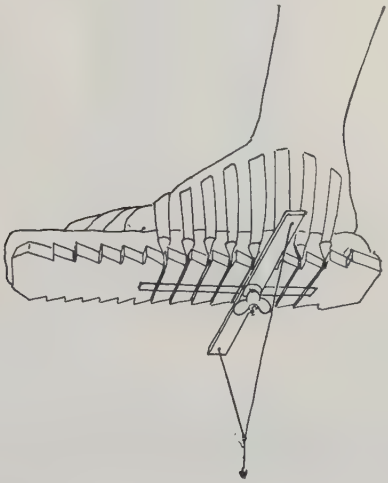


Fig. 1225.—Method of application of Sinclair skate to obtain traction in certain fractures of the lower leg.

Fig. 1226.—The Cabot posterior wire splint padded completely. Note the foot-pad of pasteboard covered by cotton cloth pinned to the foot-piece of the splint for greater security.

The side splints of wood (Fig. 1227) should be about 4 inches wide, and long enough to extend from the foot-piece to the top of the splint. The splints may be covered with sheet wadding and cotton cloth, as seen in the figure.

Fig. 1227.—Side splint of splint wood. Method of padding: (1) With sheet wadding; (2) with cotton cloth; (4) pinned in place, and then (5) stitched.

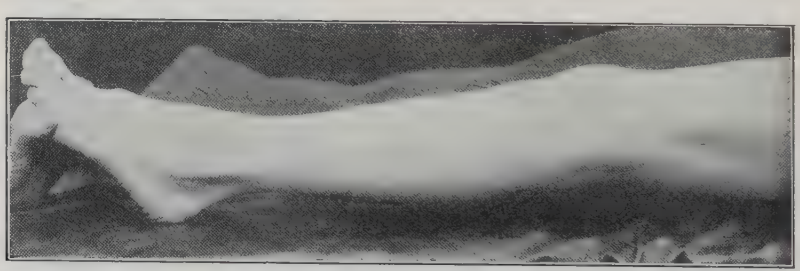


Fig. 1228.—Normal leg with foot flexed, showing that the heel rests heavily on the table (see Fig. 1229).

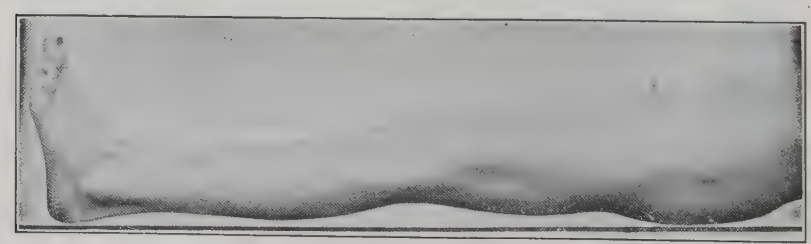
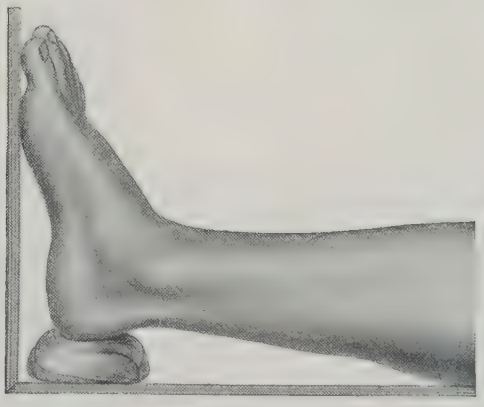


Fig. 1229.—Posterior outline of the normal leg, suggesting the necessary padding to be used on the Cabot splint. When the foot is at a right angle with the leg the heel rests lightly on the table.

a



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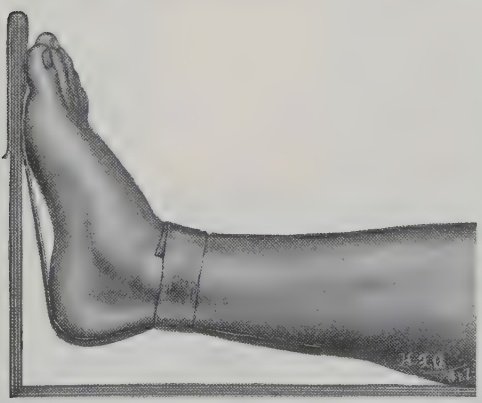


c

Fig. 1230.—Methods of supporting the foot in fractures of the leg when using a posterior splint: *a*, Padding beneath tendo achillis; *b*, ring under heel; *c*, sling of adhesive plaster.

Care of the Heel: If but slight pressure is maintianed upon the heel even for a few days, a pressure sore will develop. This is liable to increase to a considerable size. It is

very slow in healing. Many weeks after the fracture of the leg has united the pressure sore may be open. It is, therefore, of very great importance to prevent pressure upon the heel during the treatment of fractures of the lower extremity associated with dorsal decubitus. There are four methods of avoiding pressure on the heel. Position will assist materially. The position of the foot largely determines the amount of pressure falling on the heel. When the foot rests naturally, it is in the position of slight plantar flexion. The heel presses firmly upon the splint (Fig. 1228). A large part of the weight of the leg thus falls upon the heel. When the foot is extended to a right angle with the leg, the pressure upon the heel is, in a large measure, removed (Fig. 1229). Therefore, in putting up fractures of the leg the right-angle position is the desirable one. Padding above heel is of service. The ring or doughnut pad around the heel is sometimes efficient. Slinging the foot by adhesive straps applied to the sides of the heel and foot and fastened to the foot-piece of the splint is a very satisfactory method of removing pressure from the point of the heel (Fig. 1230).

Fig. 1231.—*x* Ray of fracture in child of eight years. Fracture difficult to hold reduced. Bones sutured. Excellent result.

Fig. 1232.—Fractures of the leg. Cabot posterior wire splint and side splints, showing the space to be padded on each side of the leg and thigh.

The Padding of the Posterior Wire Splint for the Reception of the Lower Extremity: Regard should be had for the natural curves of the leg and thigh posteriorly (see Fig. 1229). Above the heel, behind the knee, and below the buttock are distinct hollows, at which places the padding, as indicated in the illustration, should be thicker than at other points. Regard should likewise be had for the natural lateral curves of both thigh and leg. Just below the malleoli, above the ankle, below the knee, and above the knee are distinct hollows that will require more padding than elsewhere on the sides of the limb (Fig. 1231). The more carefully the splint is padded, the more nearly perfect will be the result of treatment and the greater will be the comfort of the patient.

The leg is to be placed upon the posterior iron splint, so padded posteriorly that it rests naturally and comfortably. The foot should be placed at a right angle, drawn down snugly to the foot-piece, and steadied by adhesive-plaster straps carried around the foot

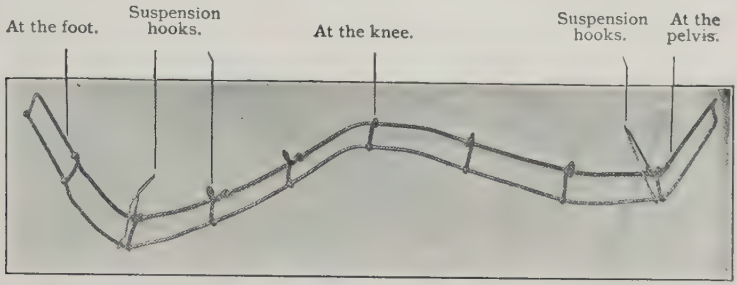


Fig. 1233.—The anterior wire suspensory apparatus of N. R. Smith. This splint is applied to the anterior surface of the padded foot, leg, thigh, and hip. The splint is fixed to the leg by a bandage. The splint is intended to immobilize the leg and at the same time to suspend it, permitting motion at the hip, and to secure extension upon the distal fragment. A plaster-of-Paris splint may be slight, conveniently suspended by this old-time splint.

and splint in a figure-of-8 bandage (see Figs. 1234, 1235). The side splints, so padded with pillow-cases or towels as to bring suitable pressure upon the leg and thigh, are applied

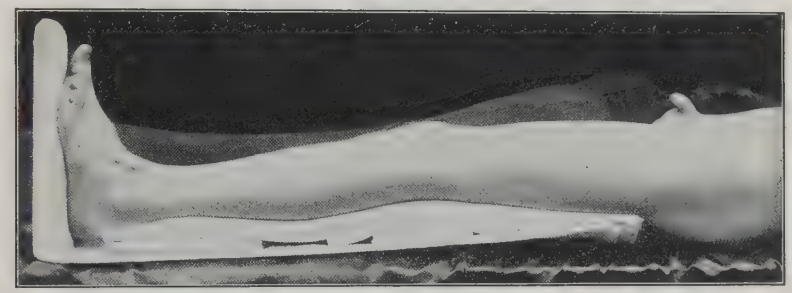


Fig. 1234.—Fracture of the leg. Cabot posterior wire splint padded properly according to the curves of the normal leg. Notice that the heel is free from the splint (see Fig. 1229).

and held in position by straps and buckles (see Fig. 1235). This splint immobilizes the knee- and ankle-joints and the fractured bones. The region of the fracture is open to

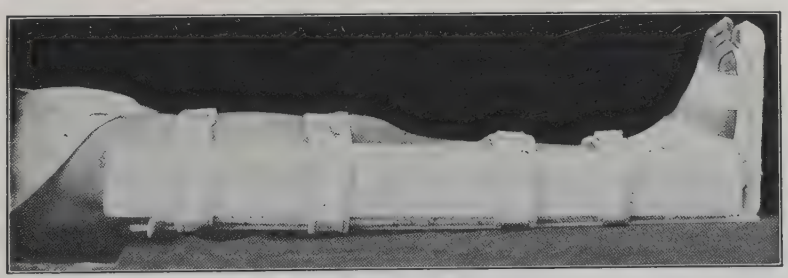


Fig. 1235.—Fracture of the leg. Cabot posterior wire splint, side and posterior wooden splints held by straps. Adhesive plaster to foot and ankle.

inspection anteriorly. Lateral inspection is facilitated by loosening the straps and lowering the side splints. Any deviation from the normal lines of the leg can be adjusted easily.

At the end of three weeks, when the fracture is uniting and the callus is still soft, the leg should be removed from the splint and examined carefully from the front, from the back, and laterally for any deviation from the normal. If any deviation is discovered, it should be corrected and the leg put again into a posterior wire splint or into a removable plaster-of-Paris splint.

The first night after splinting the fracture the patient will probably be uncomfortable. The new and restrained position, the after-effect of the anesthetic if one has been used, the points of undue pressure yet to be adjusted, the itching of the skin, the inability to move about, the necessity of lying in one position, actual pain at the seat of the fracture—all com-

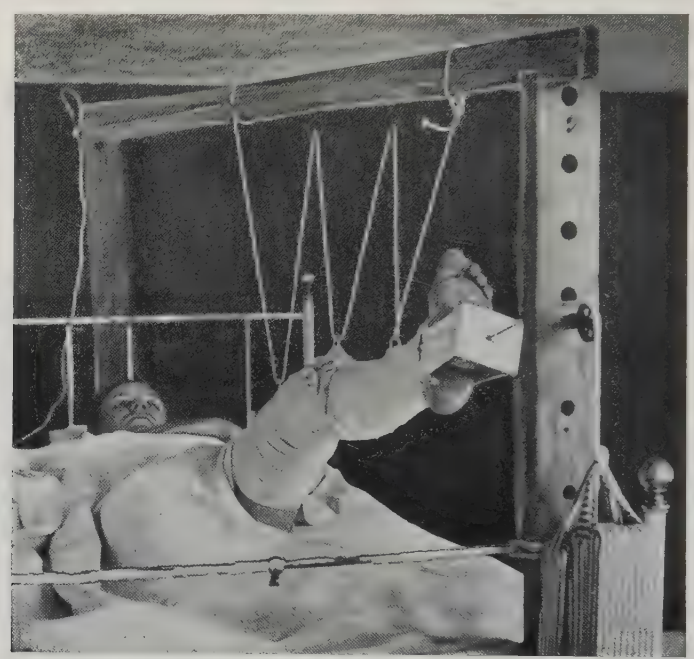


Fig. 1236.—Fracture of the thigh. Note possibility of abducting or adducting the limbs below the fracture. Note rings incorporated in the plaster anterior splint for suspension. The Smith anterior wire splint may be arranged in the same manner as shown here for the plaster anterior splint (Davison).

bine to make life miserable. It will be a wise precaution on the part of the attendant if a little morphin is administered subcutaneously this first night, as patient, nurse, and physician will rest better. After the first night there will, under ordinary circumstances, be no especial difficulty. After the plaster splint is applied the leg is to be slung just so as to clear the bed. This position is one of considerable comfort. The patient is enabled to move in bed a little and to change his position without disturbing the fracture.

Traction Plaster-of-Paris Splint.—This splint is rather of a makeshift. It may be useful to hold a position obtained under an anesthetic which the surgeon is fearful cannot be maintained by a plaster splint without added traction force.

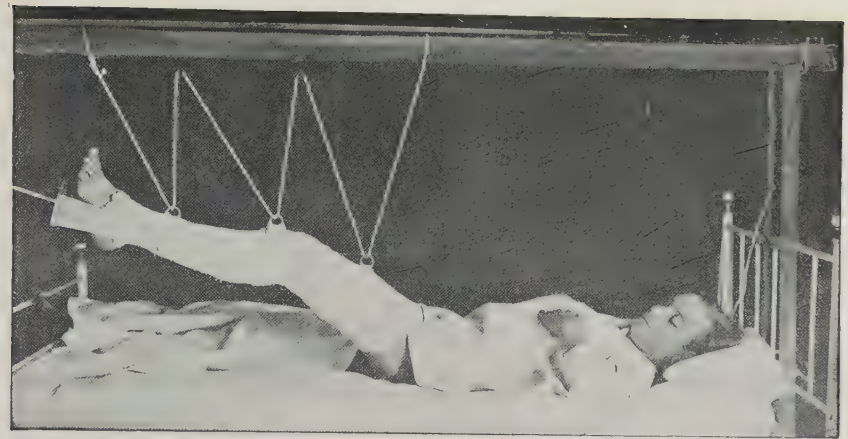


Fig. 1237.—Fracture of the thigh. Note whole limb suspended by a plaster-of-Paris anterior splint extending from instep to groin and traction secured both by the suspension of the leg and the Buck extension strips and weight (Davison).

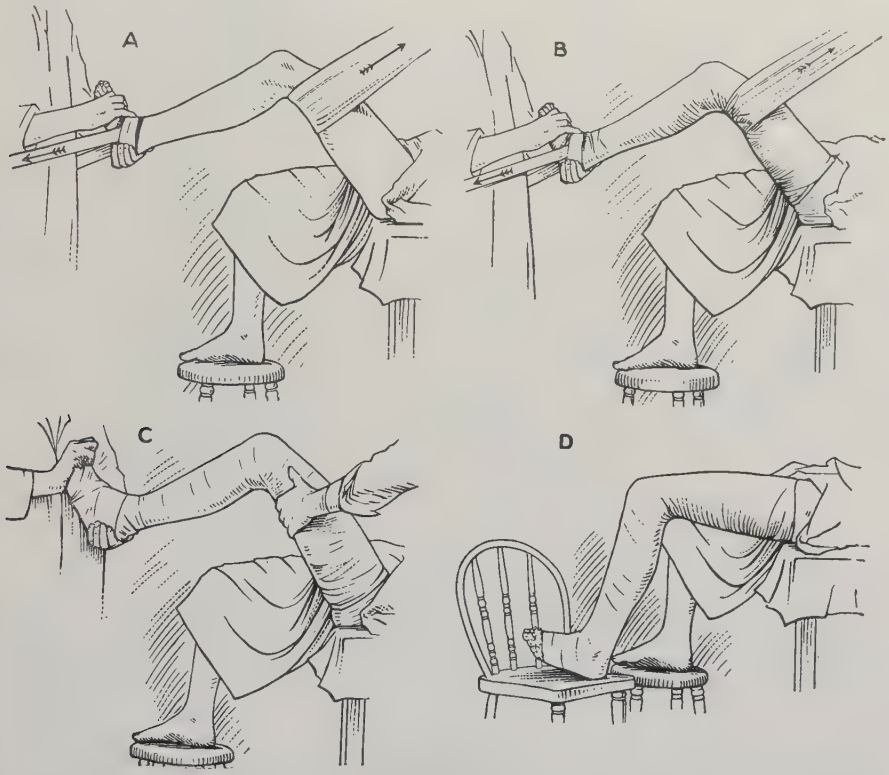


Fig. 1238.—Reduction of a fracture of the leg by the traction method: A, Traction is obtained by passing a piece of bandage about the ankle in the form of a clove-hitch, a soft pad of felt being interposed between it and the skin. The ends of the bandage are knotted about the hips of an assistant, who supports the foot manually and exerts traction by inclining the body backward. Countertraction is obtained by a supporting band passing around the lower part of the thigh which holds the knee flexed. B, In this position a plaster casing is applied in sections. The first section extends from the ankle to the groin, space being allowed for the removal of the countertraction band. C, When this has hardened, the traction bands are removed and the foot is supported manually while the remaining portion of the plaster is applied. D, Plaster completed. (Wilson and Cochrane.)

Ordinarily I believe that any case which it is impossible to hold reduced by a simple plaster-of-Paris splint should have skeletal (os calcis or bimalleolar) traction and be suspended in the Thomas splint.

The Wilson method (Fig. 1238) of direct powerful traction and manipulation with the knee flexed and immediate fixation with plaster of Paris is applicable to a certain few fractures of the leg.

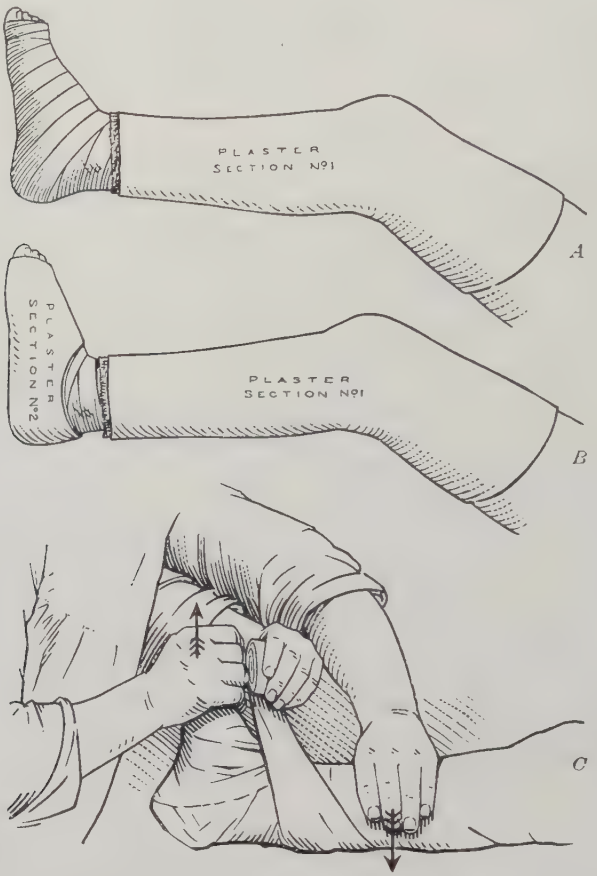


Fig. 1239.—Illustrating the three-piece sectional plaster-of-Paris casing: *A*, Drawing from a photograph, showing the first section of the plaster casing applied. Note the projecting edge of the cuff of felt. *B*, Nos. 1 and 2 sections of the sectional plaster, leaving the region of the ankle free. *C*, Drawing from a photograph to show how reduction of the posterior fracture-dislocation is effected. Note that the foot is fully dorsiflexed and slightly inverted. (Wilson and Cochrane.)

The use of two plaster splints applied to the foot and to the leg separately, leaving a space uncovered at the seat of fracture, is found by some to be effective. Traction is made on the plaster foot-piece, the foot having been carefully padded while countertraction is made above. Having the fracture reduced, the plaster splint is completed by several turns of the plaster bandage about the uncovered fracture region. Thus the reduction is maintained.

Traction is on the dorsum of the foot and heel. Countertraction is against the head of the tibia.

Obviously, this might prove a disastrous method unless very carefully safeguarded and inspected.

The heel region should be cut out and carefully finished, smooth and regular. The plaster over the dorsum of the foot should likewise be removed (Thomas).

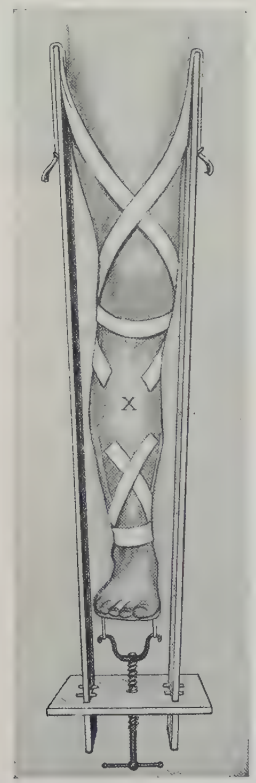


Fig. 1240.—The old-time Short-Desault splint for the application of traction to lower leg fractures. Fracture at X. Extension strips *up* from the fracture are fastened at the top of the splints. Extension strips *down* from the fracture are fastened to the foot-piece. Tightening the screw at foot-piece makes traction and countertraction. This is not now used, but serves as a model to illustrate the principle involved in Fig. 1241.

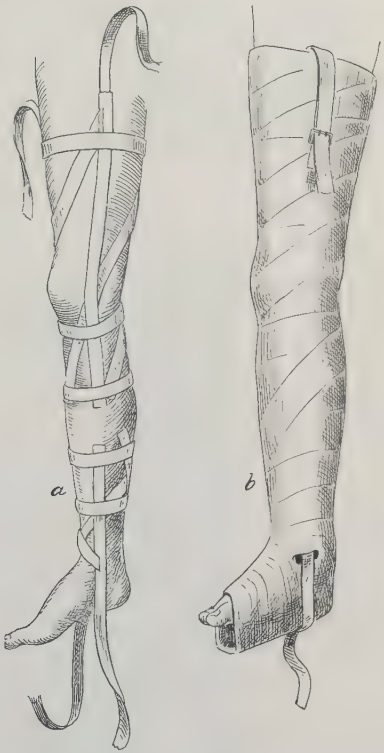


Fig. 1241.—Plaster traction splint: *a*, Application of adhesive-plaster extension strips as in Fig. 1240; *b*, plaster bandage allowing exit of extension straps. Note space left below the sole to allow for effective traction and buckles to which the upper extension is attached.

These methods are mentioned because they may prove serviceable under certain conditions.

Method of Application of the Traction Plaster-of-Paris Splint: From the seat of fracture running upward and from the seat of fracture running downward are applied extension adhesive plasters, with webbing attachments, as seen in the diagram (Fig. 1241). Below the foot, the size of the sole of the foot and 2 inches thick, is held a very firm pad of sheet wadding.

A plaster bandage is applied to the leg, according to the usual methods, from the toes to above the knee. A buckle looking upward is incorporated in the plaster bandage upon each side of the leg a little above the level of

Fig. 1242.—Cabot posterior wire splint, as used for open fractures (lateral view). Note protective padding of splint beneath wound, X, to facilitate dressings without the removal of the leg from the splint.

Fig. 1243.—Cabot wire splint in open fractures, viewed from above. Leg in position; wound of soft parts seen; dressing removed; side splints and straps seen. Upper and lower fragments held by permanent bandages during inspection of the wound.

the knee. A slit is left upon each side of the ankle for the lower extension webbings to come through (Fig. 1240). After the plaster has hardened the sheet wadding foot-pad is removed. The upper extension straps are pulled

Fig. 1244.—Fracture of both bones of the leg. Note degree of separation of the ends of fragments longitudinally. *x*-Ray taken immediately after the accident causing the fracture (Marble).

Fig. 1245.—Same case as Fig. 1244. Practically perfect reduction of the displacement of the fracture. This was accomplished by traction and manipulation under anesthesia immediately following the injury before factors hindering reduction had become operative. Early immediate reposition is relatively easy and successful (Marble).

snugly over the upper edge of the plaster splint and fastened to the buckles on each side. Then the lower straps are pulled taut over the foot-piece of the plaster. Countertraction and traction are thus maintained upon the fragments of the fracture. A window is cut in the plaster to observe the position of the bones. This apparatus is efficient in many instances in which it is otherwise difficult to maintain reduction.

Delbet's Plaster-of-Paris Apparatus (after Ashhurst[1]).—The Delbet splint for fractures of the ankle and lower part of the leg is very efficient, but has the disadvantage of being rather uncertain in setting in the hands of many users. This is enough of a handicap to prevent its being used to any degree outside of hospital practice.

In order to obviate this uncertainty Ashhurst has altered the technic in the application of plaster to the splints and believes that the difficulty has been overcome. In a series of more than 20 cases the plaster has set quickly, uniformly, and very hard in all but 1 case; in this case it was evident from the first that the fault lay in not using enough plaster of Paris.

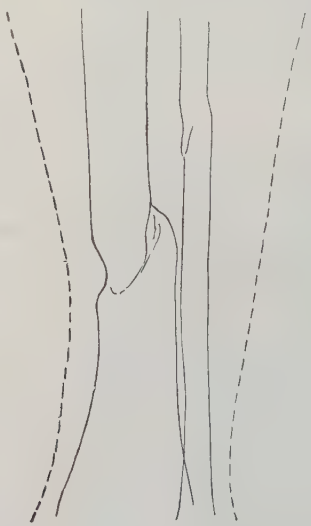


Fig. 1246.—Fracture of both bones of the leg. Ununited fracture of tibia. Fibula united (Massachusetts General Hospital, 1190. *x*-Ray tracing).

Fig. 1247.—Equinus lever of G. G. Davis. The leather strap passes across the instep and the cross-bars beneath the ball of the foot. The operator, steadying the far end of the lever in his own axilla, has complete control of the patient's foot (Ashhurst, Oxford University Press).

In the French method a plaster cream is made, and the crinoline forms are immersed in it just before being applied. The method Ashhurst has now

[1] Oxford Loose Leaf Surgery, Archives of Surgery, vol. 7, pp. 601–632.

Fig. 1248.—Equinus lever of G. G. Davis in use (Ashhurst, Oxford University Press).

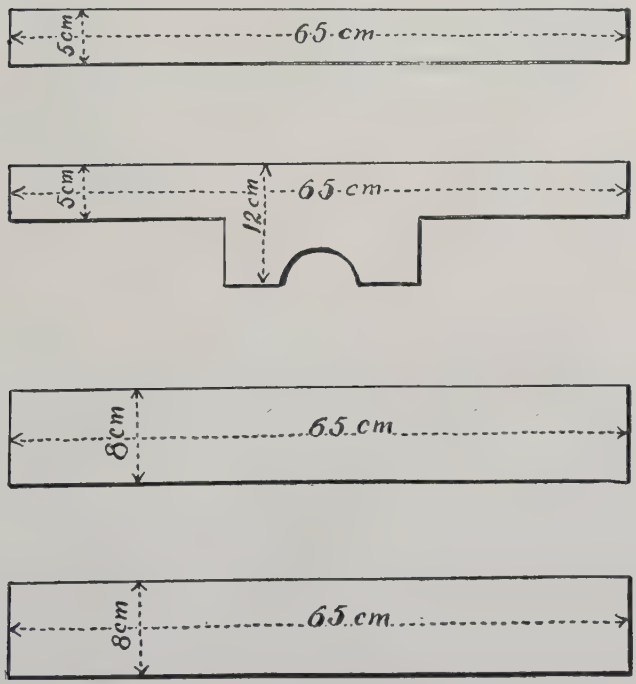


Fig. 1249.—Diagram showing the dimensions of the crinoline bands of which Delbet's apparatus is composed. The two lateral bands are made of twenty-four thicknesses of crinoline, and the circular bands of sixteen thicknesses each (Ashhurst, Oxford University Press).

adopted conforms more to the usual American method of employing plaster of Paris. The method used is as follows: The folded sides of the crinoline forms are cut open, and dry plaster of Paris is incorporated into the crinoline, layer by layer, the plaster being rubbed in with the fingers. In the foot-piece the line of stitching, running at right angles to the long axis, is omitted, in order to facilitate the introduction of the plaster. The edges of this piece are then kept from curling by fastening them with ordinary paper-clips. The forms in which the dry plaster has been incorporated are rolled loosely into a rather large roll, tied, and wrapped in waxed paper until ready for use, as ordinary plaster bandages are. When ready to use, the waxed paper is torn from the top of the roll and the form is placed in tepid water just covering it, with the open part at the top. When bubbling has ceased, and the form is soft throughout, it is removed from the water, and the excess of water is squeezed out. The splints are then applied in the usual manner (Winter).

(1) Reduction may be secured by *Delbet's method of continuous weight extension* by a stirrup applied over the instep and heel. This secures rapid reduction in the course of ten or fifteen minutes without the use of a general anesthetic and without causing any pain. When reduction is complete, Delbet's apparatus of plaster of Paris is applied, and when this has set, the weights and traction stirrup are removed.[1] Delbet considers this method especially applicable to fractures of the ankle. He says (1916), quaintly enough, that before he had perfected this method he constantly prayed that if ever he had to experience any fracture in his own person it might not be one of the ankle, since the results of ordinary treatment were so bad; but since adopting the method which is about to be described he prays that he may suffer an ankle fracture rather than any other because the treatment and results are so satisfactory.

The Delbet apparatus should be applied as soon after the accident as possible, before swelling develops: prompt reduction of the fracture is the best means to prevent the occurrence of injurious swelling. The chief advantages of the apparatus are: (1) It is applied during continuous traction on the foot by weight and pulley, this traction serving to secure accurate reduction of the fracture without any anesthetic; (2) as soon as the plaster of Paris has set, the weight extension may be removed, since the apparatus fits snugly to the condyles of the tibia above and to the malleoli below, preventing any subsequent displacement; (3) it leaves both the knee and ankle-joints free, so that the patient can move them from the start, and thus by constant use of his leg muscles can materially shorten the period required for consolidation of the bones, and prevent occurrence of the atrophy of disuse; (4) the patient can leave his bed and begin to walk with crutches during the first week or ten days; (5) the *average* time the splint was worn in Delbet's own cases was thirty-five days, the fragments being then firmly united and all external support discontinued.

[1] See Ashhurst and Crossan, Prognosis and Treatment of Fractures of the Tibia and Fibula, Trans. Amer. Surg. Assoc., 1923, xli, 594.

The materials required for the application of the apparatus are:

1. A hard flat table with no padding to support the fractured leg. Such support prevents the posterior sagging always seen when the limb is placed on an upholstered surface, such as even the firmest mattress. It has proved convenient to use a thin board which is laid on top of the mattress (Fig. 1250). A pulley is attached to the board at such a height that traction over it will be directly in the axis of the leg bones; and the pulley being movable laterally on its axis, any lateral deformity at the site of the fracture can be corrected by shifting the pulley to right or left without in any way disturbing the limb.

2. A Scultetus (many-tailed) bandage, made by stitching together at their centers enough rather narrow strips of bandage (each about 50 cm. long) to extend from the heel to the knee. The ends of this bandage may be wrapped around cardboard strips for convenience in handling.

3. Weights for traction. From 7 to 10 kg. (16 to 22 pounds) are required.

4. Material such as tarlatan or crinoline for making the apparatus. This should be cut into pieces of the following dimensions (Fig. 1249): the *two*

Fig. 1250.—Method of application of Delbet's apparatus for fractures of the leg. Note the board laid on the bed, with a pulley for weight extension; the traction loops over the instep and heel and the Scultetus bandage beneath the leg (Ashhurst, Oxford University Press).

side splints are each of 24 thicknesses, and 65 cm. long by 8 cm. wide; the band which encircles the leg below the knee is of 16 thicknesses, and 65 cm. long by 5 cm. wide; the band which encircles the malleoli and heel is also of 16 thicknesses, 65 cm. long, and cut so that its middle portion is 12 cm. wide by 19 cm. long, while its right and left thirds are only 5 cm. wide and each 23 cm. long; in the middle third a semicircular notch is cut in the projecting portion to receive the point of the heel. Each of these four splints should be basted down its middle from end to end for convenience in handling.

Application of the Delbet Apparatus.—The board with pulley attached is placed under the fractured leg with as little disturbance as possible, and an assistant holds the patient's toes to prevent rotation of the foot on the leg. The leg is cleansed and if necessary shaved. It should always be very well powdered (talc powder is excellent). As the plaster-of-Paris splints are to be applied directly to the bare skin, discomfort may arise from the hairs

sticking to the plaster while moist. Shaving will prevent this, but generous powdering is sufficient, and is more satisfactory than greasing, which tends to prevent the plaster from setting. Next the Scultetus bandage is carefully drawn under the leg, without disturbing the latter more than is absolutely necessary. A stirrup for traction is then made by passing one strip of flannel bandage (about 3 cm. wide by 45 cm. long) beneath the tendon of Achilles, and another of the same dimensions across the dorsum of the foot just below the ankle-joint. These strips are arranged so that their centers lie in the mid-line of the heel and ankle, and they are overlapped just *below* and *posterior* to the malleoli. While the surgeon holds the ends properly overlapped, the nurse sews them together; this may be facilitated by turning the overlapped ends temporarily upward above the malleoli. It is important to have the stirrup fit the ankle snugly, and to overlap the strips far enough posterior to the malleoli to prevent the line of pull from tending to force the foot into the equinus position.

Finally, the free ends of these traction slips are sewed or tied to each other at a convenient distance below the sole of the foot; and to the loop thus formed is fastened the cord passing over the pulley and supporting the weights. The weights should be added gradually up to a maximum of 10 kg. Frequently less weight is enough. As soon as the weights begin to act, the patient's pain ceases. No effort should be made to push or mold the bones into position. Any such attempt will produce pain and muscular spasm, and will totally defeat the object gained, which is the gradual reduction of the deformity. The line of pull may be altered readily by shifting the pulley to one side or the other, without causing the patient any discomfort.

As soon as reduction has been secured, as ascertained by measurement and the restoration of the normal contour of the ankle, a plaster cream should be made. About 6 cupfuls of cold water are placed in a rather shallow but large basin, and plaster of Paris is slowly sifted into the water until the powder no longer sinks rapidly. By this time a little plaster will have collected on the bottom of the basin; and then, but not until then, should the hand be put into the cream for stirring it. This stirring should be done slowly, regularly, and uniformly; no churning is permissible. Delbet says it is better to have a cream too thin than too thick. The plaster should be of the best quality, quick setting, and fresh. When the mixture is of the consistence of very thin cream, all four of the crinolin splints should be immersed at the same time, to prevent unequal distribution among them of the plaster of Paris. Sufficient time should be allowed for them to become well impregnated; they are then removed from the cream and spread out flat and in order, and their surfaces sprinkled with dry plaster of Paris.

The band which goes around the malleoli is drawn under the bridge formed by the tendon of Achilles, *without moving the leg*, and is pulled down by see-saw motions until arrested by the heel; for the time being its ends are spread out flat on the fracture board. The band which goes below the knee is next pulled beneath the popliteal space, and is drawn downward by see-saw motions until arrested by the calf; and its ends are spread out flat on the fracture

board. The two lateral bands next are applied, beginning just below the level of the knee-joint (this is at the lower border of the patella), and extending to within a centimeter of the sole of the foot at the heel; the bands are then doubled back on themselves, so that the lower third of the leg is supported by a double thickness. When these lateral bands have been gently molded to the sides of the leg and the malleoli, the circular band already in place beneath the ankle is drawn snugly around the malleolar region on top of the two lateral bands, but *without any constriction*. The long ends of this circular malleolar band are to be crossed on themselves over the front of the leg at a point *above* that at which the tendon of the tibialis anticus becomes subcutaneous. This point may be observed on the normal leg, and the splint arranged to correspond. Neglect of this will lead to the development of a pressure sore at this point. Finally the upper circular band, surrounding the condyles of the tibia, is drawn snugly, *but without constriction*, around the leg below the knee, and its ends are crossed in front at a point above the crest of the tibia, which is also liable to pressure sores. A common mistake is to put this upper circular band too high, so that it interferes with flexion of the knee.

Last of all the Scultetus bandage is fastened up, beginning at the heel; and the whole apparatus is molded carefully to the malleoli and tibial condyles as it sets. As soon as it has become reasonably firm, the weights are removed, *and the stirrup applied for extension is cut and withdrawn;* neglect to remove it may cause a slough over the dorsum of the foot or over the heel. Usually the weights do not have to remain in place for more than fifteen to twenty minutes from beginning to end of the procedure. The Scultetus bandage is removed in twenty-four to thirty-six hours, leaving the gypsum apparatus in place.

For the first day or two after the Delbet apparatus has been applied it is well to keep the limb elevated on pillows, and surrounded with ice-bags, unless there has been at the time of the accident only insignificant injury of the soft parts. This precaution tends to prevent injurious swelling and the formation of blebs. In a few cases it may be necessary to remove the apparatus on account of swelling. Blebs appear not beneath the gypsum apparatus, but on the exposed skin. They should be painted with iodin (3 per cent.) or picric acid (2 per cent.), punctured with a sterile knife, allowed to collapse, and dusted with sterile powder. Usually they may then be disregarded, and will give no further trouble. If the apparatus is not applied until swelling has developed, it is usually necessary to apply a second apparatus within a few days when subsidence of the swelling renders the first loose. Of 123 cases under Delbet's care, a second apparatus had to be applied in 68, a third in 28, and a fourth in a few cases; with only 20 patients was a single application of the apparatus sufficient.

The subsequent care and treatment of patients wearing the Delbet splint (Fig. 1251) form an integral part of the treatment and must never be neglected. Within the first week or ten days the patients are allowed to get up on crutches and are taught to walk. Putting the foot flat on the floor, they must dorsiflex the ankle and bend the knee at each step, thus bringing

into function both joints, and preventing the atrophy of disuse or joint stiffness. This active mobilization has a singular tendency to promote rapidity of union in the fracture.

Open or Compound Fractures of the Leg (p. 889 for exact details).—In general—remember that every open fracture is potentially infected—plan to treat the infection and the fracture. Prevent further infection. Do not introduce instruments or fingers or solutions into the compound wound. Protect the wound. Immobilize the leg (p. 665).

The Permanent Dressing: Every open fracture of the leg should be anesthetized for careful examination, diagnosis, and the initial dressing. The leg should be washed with soap and water and scrubbed with a gauze

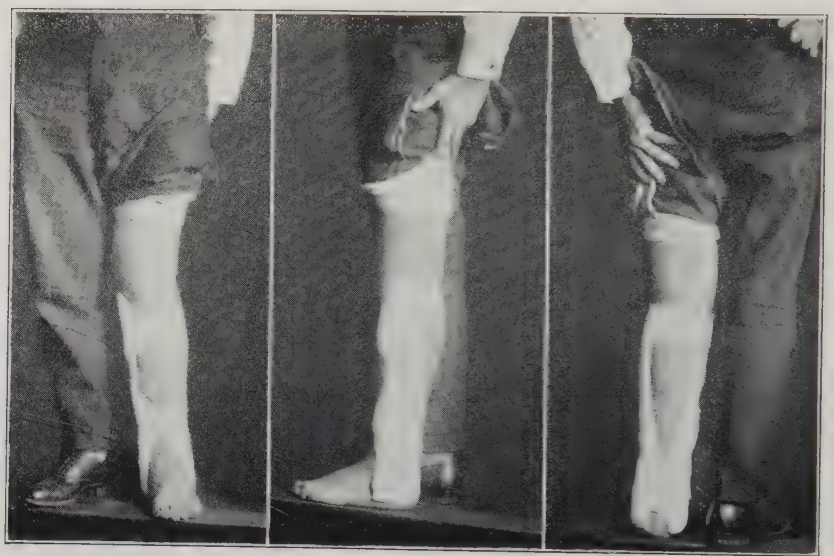


Fig. 1251.—Delbet's apparatus for fracture of the leg. Note that the weight is borne on the foot itself, not on the end of the splints. The *lower* band crosses above the prominence made by the contraction of the tendon of the tibialis anticus; the *upper* band should not come so far below the tubercle of the tibia as to press on the crest of the tibia. Note the space for the projection posteriorly of the heel (Ashhurst, Oxford University Press).

sponge or soft nail-brush. The skin should be shaved of all hair in the vicinity of the wound, and should then be washed with liquid sodæ chlorinatæ (chlorinated soda), 1 part to 20. This will most effectively free it from all grease and oily dirt. If there is no visible grease and dirt, then washing the leg with ether and alcohol, including the wound, should be done.

The Wound of the Soft Parts: This should be moderately enlarged to allow easy access to its deeper parts. There are, no doubt, cases of fracture of the bones of the leg open from within outward in which the wound is small, evidently made by the bone, in which it is prudent to seal the wound and to regard the likelihood of infection as absent. These cases, chosen in the judgment of a wise surgeon, may do well, but they may not; therefore, the author believes it is safer to advise that all wounds of open fractures

Fig. 1252.—Delbet's splint in fracture of the leg (Jour. Amer. Med. Assoc.).

Fig. 1253.—Delbet's splint in fracture of the leg (Jour. Amer. Med. Assoc.).

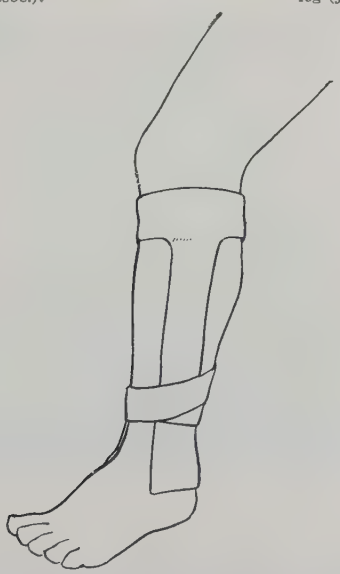


Fig. 1254.—Delbet plaster splint: Plaster strips are molded snugly without padding to the leg, one encircling the upper end of the tibia, two vertical strips on the mesial and lateral aspects of the leg, and one spiral strip holding them in position. Weight is transmitted from the upper end of the tibia to the plaster strips and by them carried to the malleoli. It is used as a convalescent brace.

be enlarged for thorough cleansing. The blood-clot and detritus should be washed out by irrigating with a warm salt solution. Irrigation should be

Fig. 1255.—Method of making gypsum molded splints (Ashhurst, Oxford University Press).

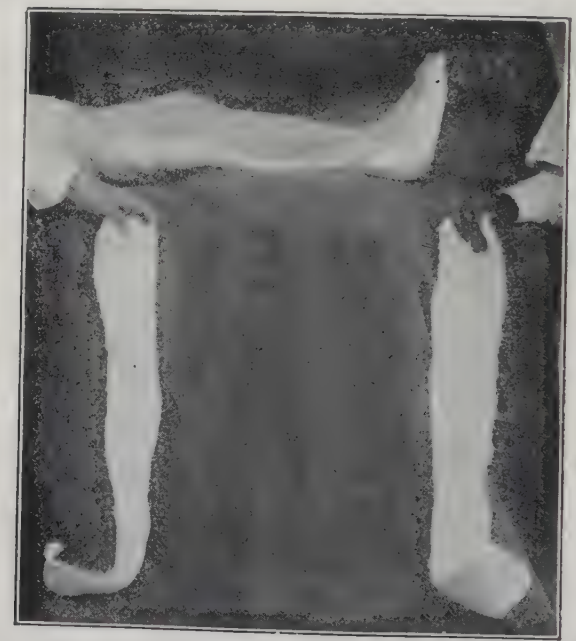


Fig. 1256.—Stimson splints of plaster of Paris showing the two lateral splints removed at the first dressing, while the limb rests undisturbed on the posterior splint (Ashhurst, Oxford University Press).

supplemented by thorough scrubbing of the tissues of the wound by small gauze swabs held in forceps and saturated with alcohol 70 per cent. These

swabs should be small enough to be carried into all the recesses of the wound. All bleeding should be checked. Loose bits of muscle, fat, fascia, and bone should be removed. A careful débridement of the wound should be made. Often the carefully protected finger will detect bits of bone when the forceps will not. The firmly attached fragments of bone are to be left undisturbed. Regarding the treatment of the slightly fixed fragments of bone, the surgeon must judge in each instance. It is a good rule when in doubt about the viability of a fragment of bone to remove it. The deep fascia may need division to permit of a view of the depths of the wound. The fractured bones are to be approximated, but not sutured until it is proved by culture that the wound is sterile. The corners of the wound may be sutured. The Carrel-Dakin treatment is to be instituted. It is wise to leave the wound open enough to receive several temporary rubber tissue wicks for drainage during the first few days. Counteropenings may be needed if one is not sure of the aseptic condition of the wound. They do no harm and may prove safety-valves against latent infection. Before leaving the wound it should be thoroughly douched with boiled water. An aseptic dressing is applied, and the leg is immobilized by the posterior wire and side splints (Figs. 1242, 1243) if no other splint is available. Ordinarily, the best splint under these conditions is the Thomas splint suspended.

Care of a Fracture of the Leg After the Permanent Dressing Has Been Applied.—All fractures of the leg will be placed, sooner or later, in the fixed plaster-of-Paris splint. One week after the splint is applied the patient may be up and about with crutches. At first the hanging of the leg down may be attended by great discomfort. There may be a sense of fulness and of burning in the leg. The leg may feel as if it would burst. The toes may look blue and be swollen. Letting the leg hang down, be dependent, for short intervals at first, and alternating with elevating the leg until the uncomfortable swelling and sensation have entirely disappeared, will enable the patient to gradually increase the time of lowering the leg until all discomfort will have vanished. As the patient becomes accustomed to these conditions, which are in themselves harmless, he will be able to ignore them; they will grow less and less troublesome and eventually disappear. At the end of five weeks the fracture should be found very firm. A lighter plaster splint may be then applied, extending only to the knee-joint, and allowing flexion of the knee. This thin plaster splint should be split, so as to be removable. After about five weeks from the injury the leg should receive a daily bath and massage, with active and passive motion to the knee- and ankle-joints. At about the eighth week the protecting splint may be removed, a flannel bandage from the toes to the knee substituted, and the patient be allowed to touch the foot to the floor, bearing a little weight. Eighty-two per cent. of fractures of the tibia will be solidly united within seven weeks (Paul). Seventy-eight per cent. of the fractures of the tibia and fibula will be solidly united within nine weeks (Paul). Fractures of both bones of the leg in children under ten years of age will require about eight weeks for solid union. As soon as the plaster is removed and the bandage substituted, a shoe, preferably laced,

should be worn on that foot. From the eleventh to the twelfth week after the injury the patient should be walking somewhat with a cane. According to present methods a fractured leg would require from three to five months of treatment before restoration to normal function is completed.

The care of a case of fracture of the leg is attended with no little anxiety on the part of the surgeon. The general health of the patient is a matter of considerable concern. The loss of exercise entailed by the cramped and unnatural position causes loss of appetite, headache, constipation, dyspeptic ills, etc. The pain through the whole limb, due undoubtedly to the sprain and wrenching at the time of the injury, the aching at night at the seat of the fracture, combine to render the patient thoroughly uncomfortable, unhappy, and even melancholy. Pressure spots will appear about the most carefully applied bandage, and they must receive attention. Itching of the skin inside the splints is sometimes almost unendurable. To every patient daily general and local massage and bathing will be found to be of unspeakable comfort. Massage, if the skin surfaces permit, may be instituted after the first week. The average hospital patient is far less sensitive to all the petty annoyances of an immovable and closely fitting dressing than is the private patient.

The Prognosis.—In children and young people the minimum time is consumed by the process of repair. The restoration of the leg to its normal function is more rapid than in the cases of adults, and there are fewer complications. In adults a chronic arthritis may appear in the neighboring knee- or ankle-joints. Swelling of the leg and ankle may persist for some time. Non-union of the bones may result, and necessitate operative measures (Fig. 1246). If the fracture is oblique, shortening may occur even after union takes place if the unsupported leg is used too soon and too much. If the wound of an open fracture heals quickly, and there is little comminution of bone, repair will take place as in a closed fracture. Otherwise, an open fracture will unite more slowly than a closed fracture. Persistent swelling of the leg, particularly about the ankle, is associated with the convalescence from an open fracture. Necrosis of bone at the seat of fracture may occur in cases of open fracture even many months or years after the original injury. Abscesses and sinuses may form, necessitating operation for the removal of the necrosed bone (Figs. 1257, 1258). For some unknown reason fractures of the upper third of the tibia unite less readily than fractures of bone elsewhere. Union is longer in being consummated. If the fracture is near the knee- or ankle-joints the prognosis is more uncertain than if the fracture is at the center of the shaft. A comminuted fracture is more likely to be longer in uniting and to give rise to trouble after repair than is a single transverse fracture.

Summary of Treatment of Fracture of the Leg.—A *crushed leg* with external wound may require to be observed for several hours to be assured of its viability. The splint under these conditions should be either a Thomas, a pillow and side splint, or a posterior wire and side splint. All these splints may be readily suspended.

A simple fracture, often of a single bone without displacement, should be treated by immediate application of a plaster-of-Paris splint, elevation of leg, slinging, plaster, splitting plaster splint.

Fractures with slight displacement rather easily corrected. The principle of the Thomas, Hodgen, and Hawley splints should be used.

Fractures with Displacement Difficult to Reduce.—The Thomas splint with or without operation and leverage, a plate or band.

Skin traction in fractures of the leg is coming to be recognized as ineffective. A fracture of the leg controllable by skin traction may properly be placed in a plaster-of-Paris splint (Leland). Fractures demanding heavy traction had best have bony traction either by a pin (Steinmann nail) through the os calcis or above the os calcis, or a bimalleolar caliper.

The pin above the os calcis causes less disturbance than the stirrup above the os calcis.

Thrombosis and Embolism.—Thrombosis of the veins about a fracture, and particularly about a

Fig. 1257.—Open fracture of both bones of the right leg in the lower third six months after the accident. Note the deformity and enlargement of the leg near the ankle.

Fig. 1258.—Lateral view of Fig. 1257. Note discharging sinuses.

fracture in which there is some laceration of the soft parts, is not at all uncommon. At times, and rather more frequently than is generally supposed, emboli are detached from these thrombi and cause almost immediate death, with symptoms of pulmonary embolism, namely, a sudden cyanosis and great difficulty in breathing associated with intense precordial distress.

Thrombosis of the veins of the leg or thigh is undoubtedly one of the causes of the great edema seen after fracture of these parts.

Refracture of the Bones of the Lower Extremity.—It is not an uncommon experience to find that a patient with a fracture of the thigh, leg, or patella refractures the partially united bone. This refracture is due to either muscular violence or a slight fall. There is ordinarily little displacement of the fragments. The callus of the original injury holds the bones quite securely. The leg is usually bent at the seat of the fracture. Refracture is, therefore, practically a fracture of callus. This accident has even occurred while the patient is wearing a protective splint of plaster of Paris. Union in these cases is much more rapid than after the original injury. About one-half the time required for union of the original fracture is necessary for union of the refracture. The patient may, therefore, be much encouraged, for though the accident of refracture is a disheartening one, yet he will not be obliged to look forward to a long confinement.

ANKLE-JOINT FRACTURES

Anatomy of the Ankle.—The anatomical relations of the lower ends of the fibula and tibia and the astragalus and os calcis should be kept constantly in mind. The os calcis and astragalus are held firmly together by

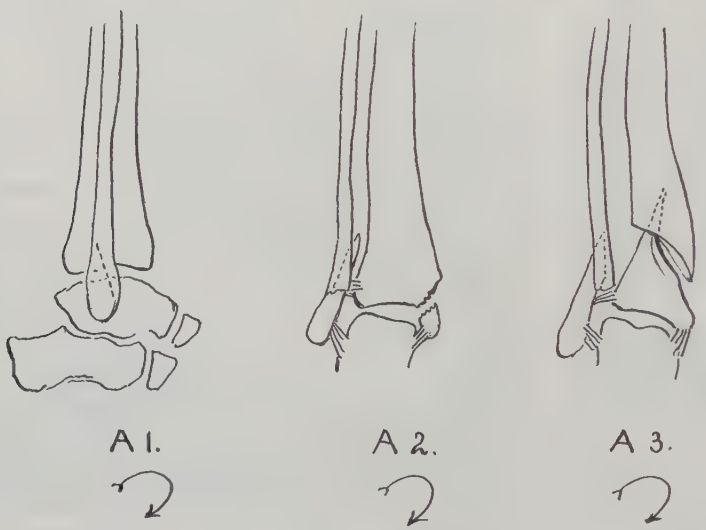


Fig. 1259.—Diagrammatic drawing illustrating mechanism of ankle fractures. The events following forcible external rotation of the foot.

the strong astragalocalcanean interosseous ligament forming the posterior portion of the foot. The astragalus rests mortise-like between the internal and external malleoli (Figs. 1264 and 1274). The strength of the inferior tibiofibular articulation depends upon the strong inferior tibiofibular ligaments, particularly upon the interosseous ligament.

Motions of adduction or abduction in the foot normally occur in the subastragalar joint. When such movements become extreme, they are trans-

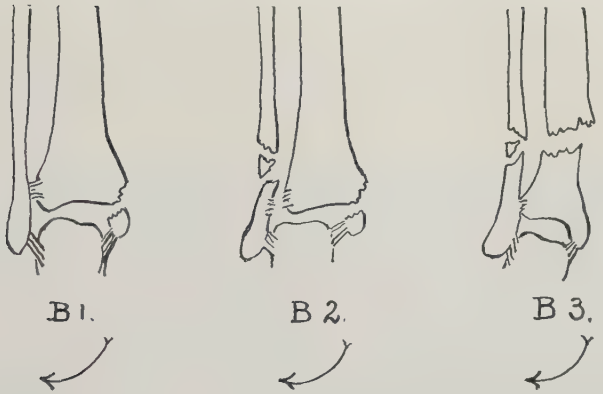


Fig. 1260.—Diagrammatic drawing illustrating the mechanism of ankle fractures. The events following abduction or fibular flexion of the foot.

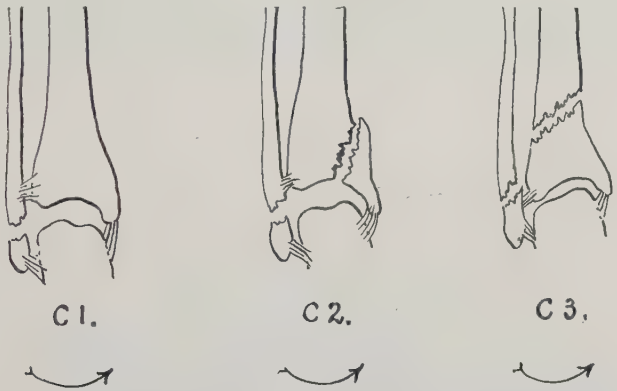


Fig. 1261.—Diagrammatic drawing illustrating the events following adduction or tibial flexion of the foot.

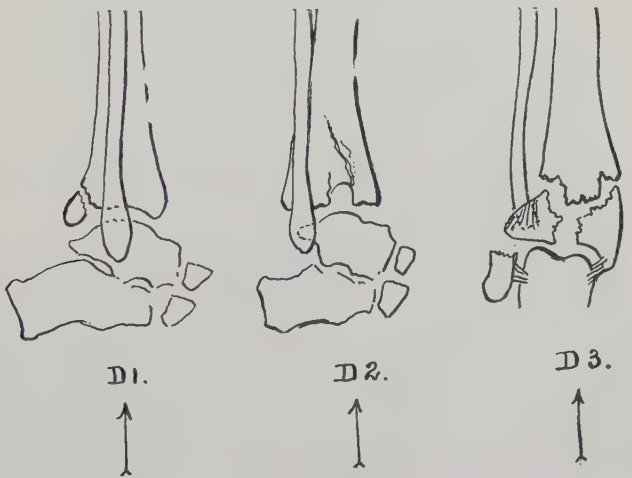


Fig. 1262.—Diagrammatic drawing illustrating the mechanism of ankle fractures. The events following force transmitted upward by falls on the foot.[1]

[1] These drawings (Figs. 1259–1262) were made under the direct supervision of Ashhurst for this edition of the fracture book.

mitted directly to the astragalus and the tibiofibular mortise, and fracture of one or the other malleolus is the common result.

Not until that malleolus on which the pull comes has given way, or the corresponding ligament has ruptured, is the astragalus able to act on the other malleolus by a pushing force which will produce a compression fracture.

The fibula is attached to the tibia in two places. There is slight motion at the points of contact between tibia and fibula below. There is no joint cavity here, union is through a dense felt-like interosseous ligament. At the upper end of the fibula there is a synovial cavity in the tibiofibula joint.

The foot is held to the leg bone by strong ligaments.

The normal movements of the ankle-joint are those of flexion and extension, 20 degrees of dorsiflexion and 60 degrees of extension or plantar flexion.

Mechanism of Ankle Fractures.—Most fractures of the tibia and fibula which involve the ankle-joint are due to forced movements in one of three directions: A. Fractures by external rotation. B. Fractures by abduction or fibula flexion of the foot. C. Fractures by adduction or tibial flexion of the foot. D. Then there are fractures dependent on the force being transmitted upward by falls on the foot. These will be comminuted and at times compound.

The classification and sequence of events in an ankle-joint fracture is, according to Ashhurst,[1] grouped into four classes, A, B, C, and D, as follows:

A. Fractures due to forcible *external rotation* of the foot:
   1. Spiral of lower end of the fibula.
   2. Rupture of internal lateral ligament. Fracture of the internal malleolus.
   3. Lower end of the tibia. Spiral of the lower end of the fibula.

B. Fractures due to *abduction* (or fibular flexion of the foot):
   1. Internal malleolus or rupture of the internal lateral ligament.
   2. Fracture of the fibula { (*a*) Below inferior tibiofibular joint (bimalleolar). (*b*) Above inferior tibiofibular joint (Potts).
   3. Internal malleolus represented by the whole lower end of the tibia.

C. Fractures due to *adduction* (tibial flexion):
   1. External malleous transverse.
   2. Followed by { (*a*) Internal malleolus (bimalleolar). (*b*) Median tibial surface, up and in from joint.
   3. Whole lower end of tibia (supramalleolar).

D. Fractures due to falls on the foot.

By Pott's fracture of the ankle is understood the injury caused by forcible eversion and abduction of the foot upon the leg. The lesions which may be present in this fracture are a rupture of the internal lateral ligament, a fracture of the tip of the internal malleolus, a separation of the lower tibiofibular articulation, an oblique fracture of the fibula 2 or 3 inches above the tip of the external malleolus, a fracture of the outer edge of the lower end of the tibia. Ordinarily, the mechanism of the fracture is somewhat as follows: As the foot is abducted the strain is felt at the internal lateral ligament and at the inferior tibiofibular interosseous ligament, and these give

[1] Archives of Surgery, January, 1922.

way. If the force continues, the fibula breaks. If the force still continues, the internal malleolus is pushed through the skin, and an open fracture results (Fig. 1263). If the internal lateral ligament holds against this lateral force, the tip of the internal malleolus may be pulled off.

Fig. 1263.—Open Pott's fracture. Wound in soft parts and protruding tibia to be seen.

Causes of Ankle Fracture.—Most fractures of the ankle are due to indirect violence or torsion through the mortise of the ankle-joint. A twist of the foot, a slipping from a slight height, a fall on the foot in an abducted or ad-

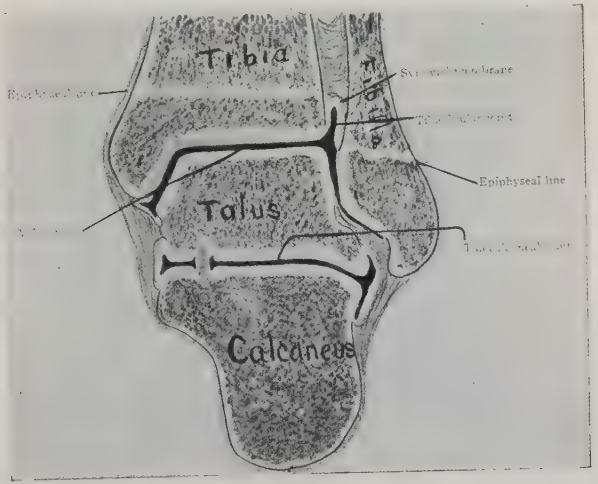


Fig. 1264.—A coronal section of the ankle-joint. The epiphyseal line of the tibia is entirely outside the ankle-joint. The epiphyseal line of the fibula impinges on the joint on its inner aspect (Thompson, Annals of Surgery, 1898).

ducted position, these are the common occasions of a fracture in the ankle region.

Fracture of the posterior articular margin of the tibia, caused probably by a direct upward and backward thrust of the astragalus, helped perhaps by an avulsive force through the posterior inferior tibiofibular ligament, is

not an uncommon complication of ankle injuries due to external rotation. The lipping fracture of Speed.

Posterior dislocation of the foot is associated often with this particular lesion, and it is thought not to occur without such a marginal fracture (see Fig. 1277). I record here a case of posterior dislocation of the foot with-

Fig. 1265.—Normal leg and foot at a right angle. Note the relative position of heel and leg.

out fracture of the tibia from the clinic of H. E. Conwell, Alabama, a unique case.

Diagnosis.—After the swelling of the ankle has occurred, which is associated with an ankle fracture, an accurate diagnosis will be difficult to make by inspection and palpation.

Fig. 1266.—Pott's fracture. Posterior displacement of the foot on the leg. Note the shortening of the foot from the toe to the front of the ankle. Compare the relative position of the heel and leg with the same in Fig. 1265.

A Roentgen ray in two planes should always be obtained; this will reveal unsuspected fissures and important slight displacements.

Tenderness should be sought: (1) On the fibula above and below the inferior tibiofibular ligament; (2) over the internal malleolus, and (3) over the tibiofibular joint.

In all cases of injury about the ankle-joint a fracture should be suspected until proved absent (Ashhurst).

The existence of a posterior marginal (lipping) fracture must be always in mind if there is considerable dislocation backward of the foot on the leg. For unless especial care is exercised to reduce and maintain the reduction very effectively, the foot will slump backward, the dislocation will recur, due to the marginal or lipping fracture of the posterior edge of the lower end of the tibia (Figs. 1266, 1551). This fracture may be recognized, apart from the *x*-ray, by tenderness over the site of fracture and by ecchymosis to one side or the other of the tendo achillis at a level with the joint and a little above. The lower end of the tibia anteriorly will be more prominent than usual, the dorsum of the foot will be shortened.

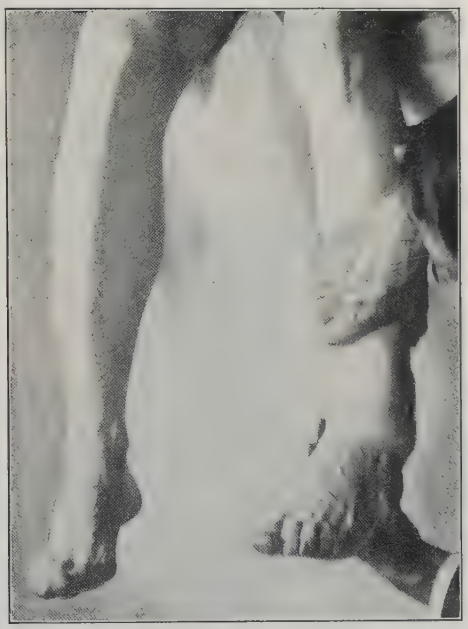


Fig. 1267.—Pott's fracture of left ankle. Method of examining ankle. Lateral mobility shown. Note the grasp of the foot and the leg.

Symptoms.—The ankle presents a very constant appearance after this fracture. A traumatic synovitis exists. Great swelling appears, at first chiefly upon the inner side of the ankle. The ankle-joint becomes distended with blood and serum. All the natural hollows about the joint are obliterated. The foot is everted, appearing to have been pushed bodily outward. The internal malleolus is unduly prominent. Some of this prominence is masked by the swelling (see Fig. 1271). The bony connections and natural support of the foot having been removed, the inferior tibiofibular ligament ruptures, the foot drops backward, partly because of the pull of the calf muscles, but chiefly because of its own weight (Figs. 1265, 1266). Speed has called attention to the fact that in ordinary Pott's fracture a posterior displacement

of the foot does not occur. If a posterior displacement is present it is because the external malleolus is free from the external side of the lower end of the

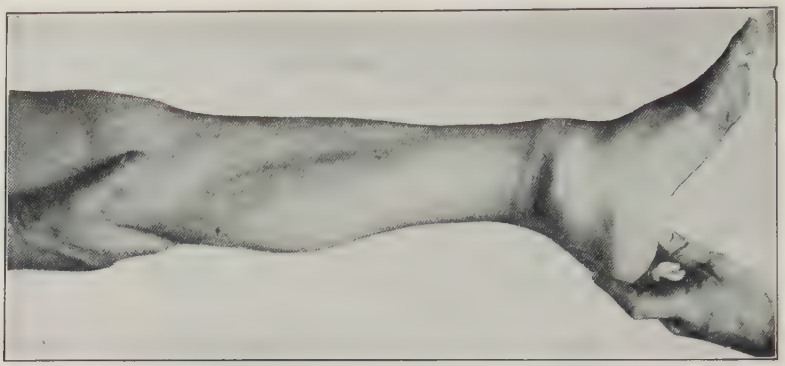


Fig. 1268.—Fracture of the internal and external malleoli and displacement of the foot inward and backward. Note prominence on front of ankle.

tibia. The deformity, therefore, is a double one, a lateral sliding of the foot outward and an anteroposterior dropping of the foot backward. The malleoli

Fig. 1269.—Same as Fig. 1268. Lateral displacement of foot inward (see *x*-ray tracing, Fig. 1272).

are spread apart; the measured distance between them is increased over the normal. Palpation close above the anterior articular edge of the tibia and the astragalus reveals tenderness over the ruptured tibiofibular ligament.

The backward displacement is best measured by the length of the line from the front of the ankle to the cleft between the first and second toes. This line will be found shortened upon the injured side. There is tenderness over the fracture of the fibula. If the internal malleolus is fractured, the sharp

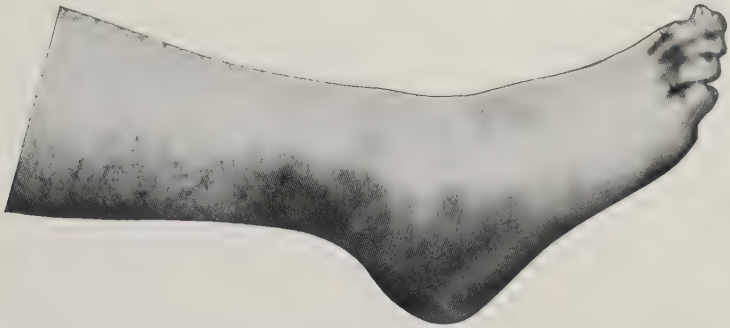


Fig. 1270.—A posterior displacement of the whole foot because of a Pott's fracture.

ridge at the broken edge can be distinctly felt. Grasping the posterior part of the foot firmly with the whole hand, while the other hand steadies the lower leg just above the ankle, abnormal lateral mobility of the foot may be detected (Fig. 1267). The foot will be felt to move inward to its natural

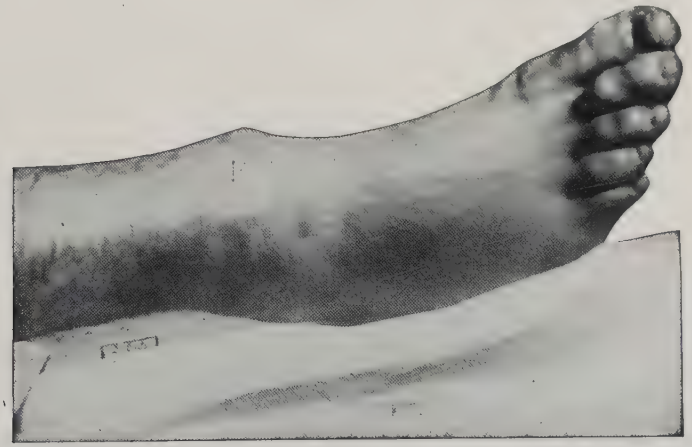


Fig. 1271.—A lateral displacement of the foot to the outer side because of a Pott's fracture. Note prominent internal malleolus and swelling of the ankle. The normal bony landmarks are not seen. The pathological bony landmark is evident.

position. The moment inward pressure is removed the foot will be seen and felt to slump outward again.

Figures 1268 and 1269 illustrate a reversed Pott's deformity, the foot having moved inward instead of outward as well as having fallen backward.

Treatment.—If the fracture is subperiosteal and is without displacement, simple adhesive strapping may be used, but weight bearing should not be

allowed until the bone has had time to unite. In the after-care of these injuries attention should be paid to the inevitable tendency to flat or pronated feet.

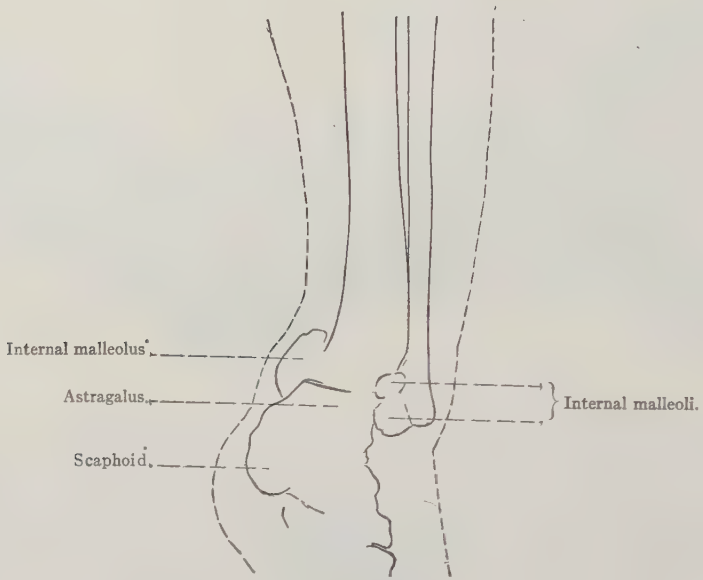


Fig. 1272.—Fracture of both malleoli (anteroposterior view). Inversion of foot (*x*-ray tracing)

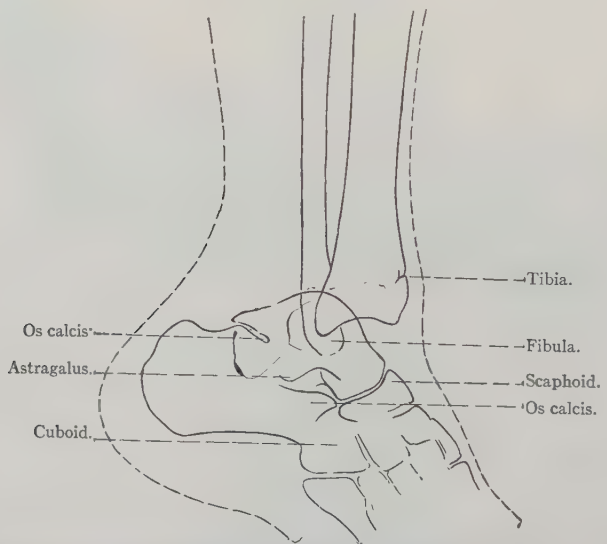


Fig. 1273.—Fracture of the tip of each malleolus. Dislocation of the foot backward. Note the prominence in front of the ankle. Same case as Fig. 1272 (*x*-ray tracing).

Fractures With Displacements.—Immediate reduction in every case should be secured as early as possible. The indications for treatment are to place the parts in their normal relations, and to maintain them so until repair is

completed, guarding against both the lateral and the posterior deformities. If, for any reason, such as the presence of very great swelling of the ankle, it is expedient to delay reduction, the leg should be placed temporarily in a

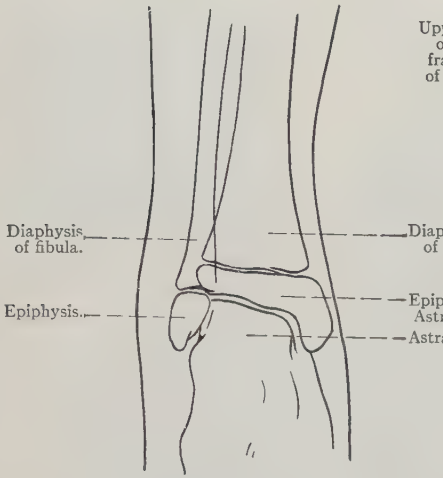


Fig. 1274.—Normal ankle-joint, showing epiphyses (anteroposterior view).

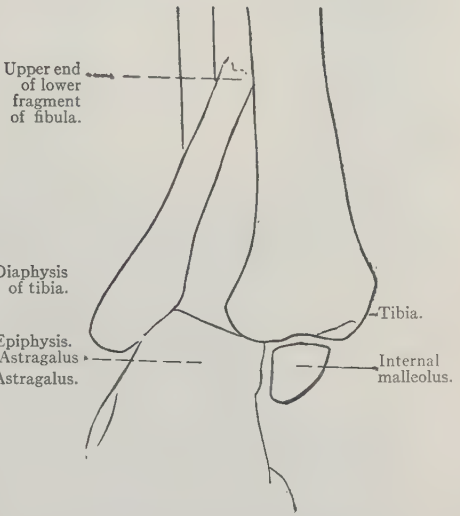


Fig. 1275.—Pott's fracture (anteroposterior view). Note sliding of astragalus outward. Fracture of internal malleolus. Fracture of fibula. Extreme deformity (*x*-ray tracing).

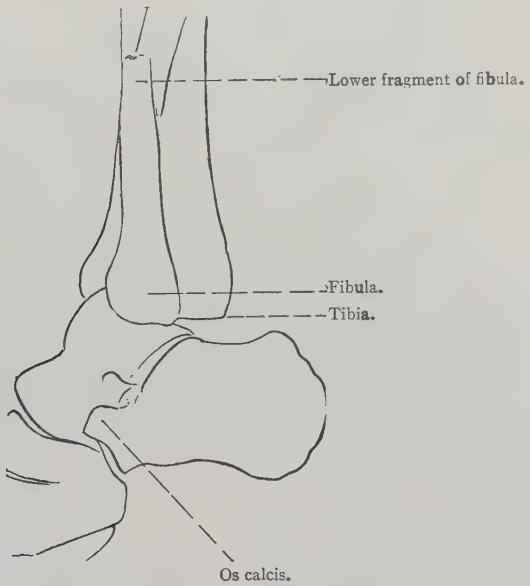


Fig. 1276.—Pott's fracture. Same as Fig. 1275 (lateral view). No fracture of the posterior edge of the tibia at ankle-joint, hence no posterior displacement.

pillow and side splints (Figs. 1215–1217). The earlier reduction is accomplished, the sooner will the swelling disappear. An anesthetic should always be administered to the patient before the reduction of this fracture. The

reduction is thus rendered painless and, through relaxation of the muscles, is made far easier.

Reduction Without Continuous Traction.—In most fractures about the ankle-joint this is the method of reduction, by manipulation and traction on the foot and by adduction or abduction of the foot.

A general anesthetic is needed, for the manipulations are extremely painful.

If the displacement is the common one, with the foot outward and backward, the surgeon pulls the foot downward away from the leg firmly and

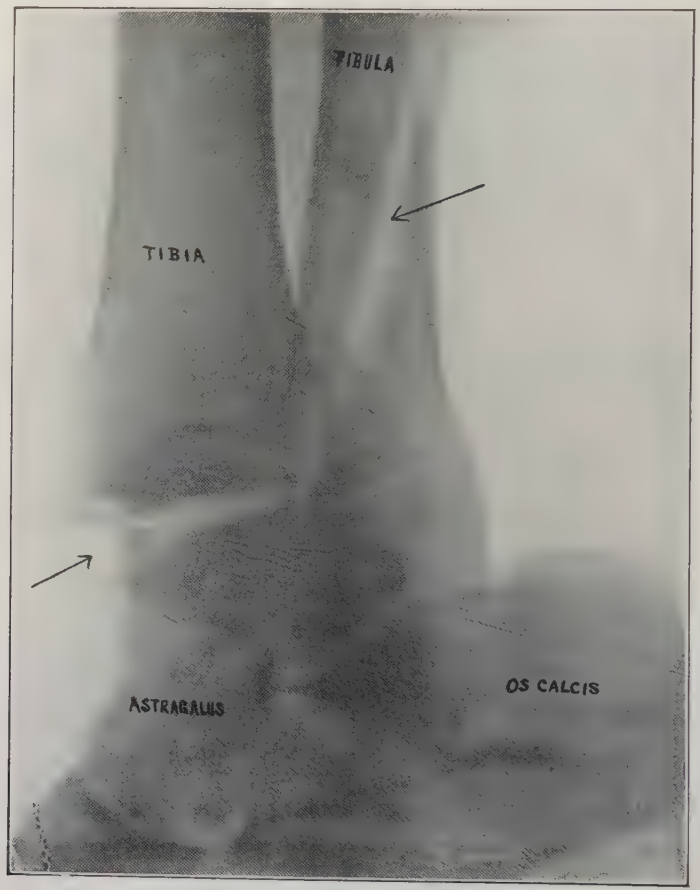


Fig. 1277.—Fracture of the internal malleolus and of the lower end of the fibula. Arrows point to lines of fracture. Posterior lipping fracture of tibia. May be well reduced without operation. Important to correct backward displacement of the foot.

continuously with the foot in plantar flexion, then, with the heel in the palm of one hand and with the other hand resting on the front of the anterior surface of the lower end of the tibia, he presses the leg backward while he dorsally flexes and lifts the whole foot forward. The foot will, with this traction and lifting, gradually resume its normal anteroposterior position beneath the leg. There is only the lateral displacement

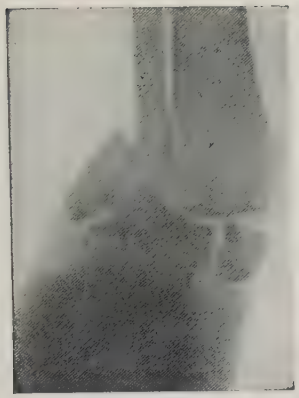


Fig. 1278.—Note rotation of foot on anteroposterior axis.

Fig. 1279.—Note sliding of foot to outer side.

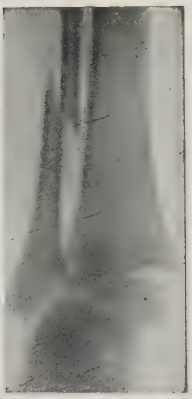


Fig. 1280.—Separation of lower epiphysis of tibia and fracture of fibula.

Fig. 1281.—Note sliding of foot without rotation.

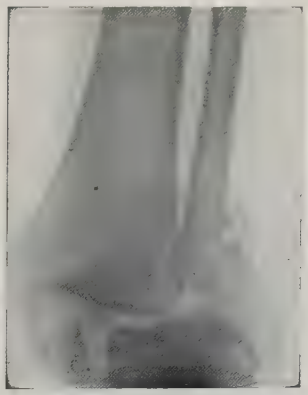
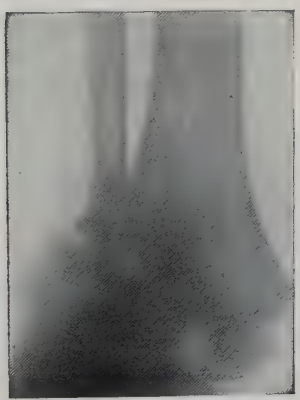


Fig. 1282.—Note extreme displacement.



ig. 1283.—Great displacement of the foot. Note prominent internal malleolus.

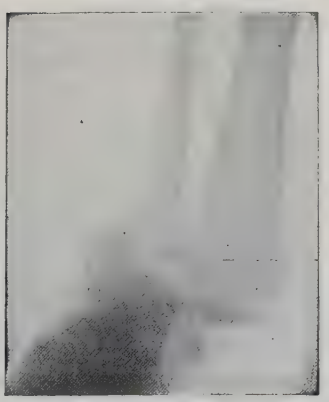


Fig. 1284.—Note displaced malleoli.

Figs. 1278–1284.—Types of fracture near the ankle-joint.

to be corrected by turning the heel strongly into adduction and crowding it hard over. The foot should be dorsiflexed to a little less than a right angle, so as to prevent recurrence of the posterior displacement. The foot should be overcorrected in adduction, so as to bring the lower fragment of the fibula in close contact against the outer side of the lower end of the tibia by traction on the external lateral ligament. Retention of this replaced fracture will best be secured by the application of the molded plaster-of-Paris splints (Stimson, see p. 707).

Application of the Stimson Plaster-of-Paris Splint (see Figs. 1289–1291).—The foot and leg as far as the knee are covered with flannel bandages while the plaster-of-Paris splints are being made. The foot and leg are held carefully by assistants.

Plaster splints are made by soaking a roller plaster bandage 10 cm. wide and running it back and forth on itself as it is unwound until a splint of suitable length (about 85 cm.) has been formed; two or three roller bandages of average length are required to make a splint of proper thickness.

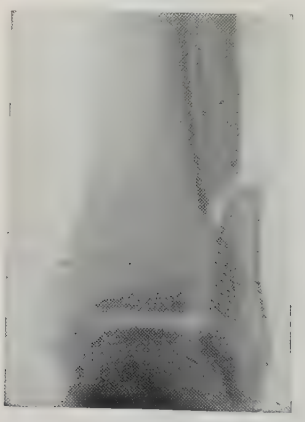


Fig. 1285.—Fracture of the fibula without fracture of the tibia. No lateral displacement of foot (Dodd).

Fig. 1286.—Same case as Fig. 1285. Note change in fibula fragments, with comparatively no change in the relation of astragalus to the lower end of the tibia (Dodd).

This splint of plaster of Paris is one of the most satisfactory for retaining ankle fractures that have been completely reduced.

The Lateral and Posterior Plaster-of-Paris Splints (the Stimson Splint).—The *posterior* splint (Fig. 1289) extends from the toes along the sole of the foot around the back of the heel and up the back of the leg to the knee or to the middle of the thigh. The *lateral* splint (Fig. 1290) begins at the external malleolus, passes over the dorsum of the foot to the inner side under the sole, and upward along the outer side of the leg to the same height as the posterior splint. Each of these splints is made of about 6 or 8 strips of

washed crinoline, 4 inches wide and long enough to extend from around the foot to the bend of the knee or middle of the thigh. The leg is protected by roller bandages of sheet wadding. Plaster cream is rubbed into the crinoline strips one after the other until all the strips have been used. The posterior splint is applied first, and held snugly by a gauze bandage to the leg and foot. Then the remaining crinoline strips are likewise covered with plaster cream and applied as the lateral splint (Fig. 1291). This is also held snugly by a gauze bandage to the leg and foot. During the application of the splint and until the plaster of Paris has set the foot should be held in a corrected position by an assistant. These two plaster-of-Paris splints are preferable to the encircling plaster splint, the ordinary "plaster leg," for by their use the ankle can be inspected. Less judgment is requisite in its application to insure the correction of the deformity than by the use of the ordinary "plaster splint." As the swelling subsides and the plaster becomes loose, if the splints are kept tight by bandaging, the deformity cannot possibly recur.

Injurious swelling is next to unknown, and fractures thus treated seldom give trouble from swelling during convalescence.

The *principles of the Dupuytren splint* (see Figs. 1287, 1288) are the ones to be applied in the reduction of this fracture whatever the apparatus in which the leg is permanently placed. These consist of the making of lateral outward pressure upon the internal malleolus, lateral inward pressure upon the foot, and a forward lift upon the posterior part of the foot or heel. If it is impossible to correct the posterior foot displacement, a tenotomy of the tendo achillis will facilitate reposition. The practitioner may very properly use the Dupuytren splint. It is thought to be uncomfortable, but it is not if properly applied. It is very efficient in holding the fracture reduced.

The Dupuytren Splint.—This is a board from $\frac{1}{4}$ to $\frac{1}{2}$ inch thick, long enough to extend from the middle of the thigh to 6 inches below the sole of the foot, and as wide as the calf of the leg from front to back (Fig. 1287). At its lower or foot end it is serrated with three or four teeth, as seen in the illustration. It is padded with folded sheets, so that when it is applied to the inner surface of the limb the padding extends to just above the level of the internal malleolus, the serrated end of the splint projecting 6 inches below the sole of the foot. The padding, as seen in the illustration, is so thick at the lower end over the internal malleolus that sufficient room is left for inversion and rotation of the foot upon its anteroposterior axis without its impinging upon the splint in the least. The splint is held in place by straps and buckles: one is placed above the ankle, one above the knee, and a third is placed at the upper end of the splint. For the proper application of the splint an assistant is needed. The splint is applied while the leg rests upon the bed. An assistant steadies the splint and the leg so that they both project clear of the foot of the bed. A roller bandage is then applied in circular turns about the ankle and splint from the splint toward the leg. After two circular turns are made the assistant adducts and inverts the ankle and foot, and this position is held by the third turn of the bandage, which is passed around the forward part of the foot and over one of the serrations of the splint (Fig. 1288). In order to hold this firmly a turn is then taken around the ankle. A figure-of-8 is then applied for several turns about the foot and ankle, crossing the ankle in front of the instep at each turn. Each succeeding turn is caught by the succeeding serration of the splint. At the same time the foot is lifted forward by pressure from behind, and this forward lift is maintained by circular turns of the bandage. The whole limb is placed upon pillows. Thus the eversion and posterior dropping of the foot are corrected.

This splint forms a good temporary or emergency dressing for Pott's fracture. This dressing corrects the eversion, but there is great danger that the foot may slump backward unless most carefully watched. This failure to hold the posterior displacement corrected is the chief defect of the Dupuytren splint.

The Posterior Wire Splint with Curved Foot-piece (Figs. 1289–1291).—This splint is described because it may at times meet certain conditions better than some other form of immobilization. It is not in common use. The posterior wire splint should extend to the middle of the thigh when used in treating Pott's fracture. The foot-piece should be twisted at the ankle, so as to hold the foot when inverted (Fig. 1292). The splint is covered and padded in the usual way. The patient is anesthetized. The leg is

Fig. 1287.—Pott's fracture. Dupuytren's splint. Note length of splint; position of straps; arrangement of padding; space between foot and splint.

Fig. 1288.—Pott's fracture. Dupuytren's splint. Note serrations of splint and turns of bandage adducting foot.

placed upon the splint. The foot is strongly inverted by great lateral pressure put upon the posterior part of the foot. This inversion of the foot cannot be made too strongly, for the deformity cannot be overcorrected. The position of extreme inversion is not a painful one to maintain. Ordinarily, the lateral pressure applied is too slight entirely to correct the deformity. The foot is held to the inverted foot-piece by straps of adhesive plaster, pads, and side splints (Fig. 1293). A pad is applied to the sole of the foot, and so placed as to maintain the long anteroposterior arch of the foot. It is found that if this is not done, there is considerable flattening of this arch upon recovery. The forward lift upon the foot is made and maintained by proper padding posteriorly to the lower leg and just above the heel (Fig. 1291). The lift may be reinforced by smoothly applied strips of adhesive plaster placed laterally on the foot and carried under the heel and up and over

Fig. 1289.—Pott's fracture. Stimson's splint. Posterior plaster (represented 2 inches too long at the upper end).

Fig. 1290.—Pott's fracture. Stimson's splint completed. Lateral plaster and posterior plaster.

Fig. 1291.—Pott's fracture. Stimson's splint removed. Lateral and posterior plasters.

the end of the foot-piece. These adhesive-plaster strips serve as a sling for the foot. There is one other way to avoid pressure upon the point of the heel, and that is by placing beneath the heel a ring of sheet wadding covered with a tightly wound bandage (see Fig. 1291). These methods of protecting the heel from pressure may all be used at one time to advan-

tage. The side splints are applied with great care, being so padded as to maintain the outward pressure upon the inner surface of the lower end of the tibia, and the inward pressure upon the outer surface of the foot. Very great care must be exercised that there is no recurrence of the deformity. Frequent readjustments are necessary.

Reduction may be secured and held by the *Delbet method* of continuous weight extension by a stirrup applied over the instep and heel (see p. 680 for method of applying this apparatus). It is ordinarily used in fractures of the leg where continuous traction is needed.

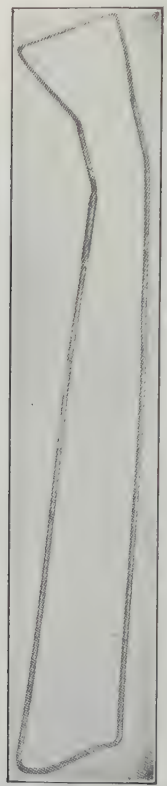


Fig. 1292.—Cabot posterior wire splint bent at the ankle for Pott's fracture of the right leg. To be used to assist in maintaining adduction of the foot.

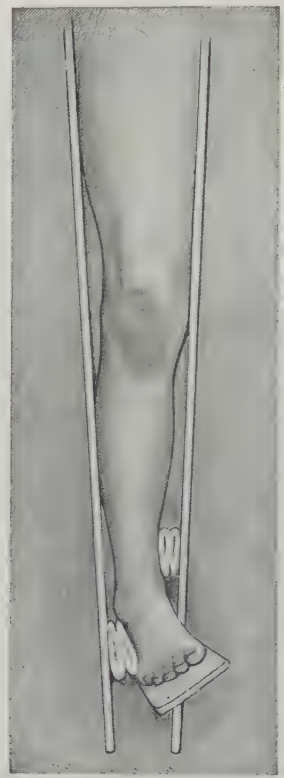


Fig. 1293.—Pott's fracture. Cabot posterior wire splint and side splints. Note position of lateral pads and twisted foot-piece. Side splints are shown unpadded. To be used if for some reason a Stimson or Delbet splint is impracticable. The foot can be held forward on the leg, *i. e.*, any posterior displacement corrected. The eversion can be corrected as seen in this illustration. Of course, the side splints are suitably padded about thigh and upper leg.

Care of the Fracture After the Permanent Dressing is Applied.—If the posterior and side splints are used: After the initial swelling has subsided, *i. e.*, after the first week, the leg may be placed in a plaster-of-Paris splint (circular bandage), and the patient allowed up and about with crutches. The plaster should be split after application and held in place by straps or a bandage.

If the Stimson splint is used the patient may be allowed up and about with crutches at the end of the first week. Massage may be applied to the

exposed parts of the leg and foot daily. At the second week all dressings should be removed, and gentle massage applied to the whole leg from toes to groin, especial attention being paid to the region of the ankle which is carefully supported. Massage and gentle passive motion in an antero-posterior direction only should be applied at least once or twice daily after the second week. All lateral motion is to be avoided. After the fifth or sixth week a knitted or flannel bandage will be all the support needed, although comfort may demand a thin, stiff, retentive splint at times. At the end of two months some weight may be borne upon the foot.

Of the three methods of dressing a Pott's fracture the posterior and lateral plaster splint of Stimson is by far the simplest and it is efficient in

Fig. 1294.—Old fracture of tibia and fibula with compensatory and actual deformity (Feiss).

Fig. 1295.—Old fracture of ankle with actual deformity (Feiss).

every way. Moreover, it allows of massage being instituted early with the least disturbance to the ankle. The posterior wire splint is more difficult of application, and needs careful watching and frequent readjustment. With the posterior wire splint in use the foot or leg is easily accessible to early massage by simply loosening the side splints.

Convalescent Care of Fractures at the Ankle.—If Delbet's splint has been used the patient may be up out of bed the first week. He may be taught to walk between crutches, bearing at first a little weight on the injured ankle and gradually he may bear all his weight, provided, of course, that the Delbet protecting splint continues snug and continues to protect. The splint should be reapplied if it loosens. After five or six weeks all the weight may be borne on the ankle.

I believe that it is important that the broken ankle during these weeks of protected walking and while the healing process is progressing should be elevated when the attempts at locomotion are finished. The eventual progress of the ankle injury toward complete usefulness will be hastened if freedom from swelling is maintained during this period.

If Stimson's splints are used they may gradually be omitted, one by one, and their places taken by a carefully applied and supporting knitted bandage. While the patient gets about with crutches, the shoe of the injured ankle

Fig. 1296.—*x*-Ray of actual bony condition before operation (Feiss).

should have its inner edge of sole and heel slightly raised to help in keeping the weight-bearing surfaces balanced.

In certain cases a pad in the instep on the inner side may be helpful, as if for a pronated foot.

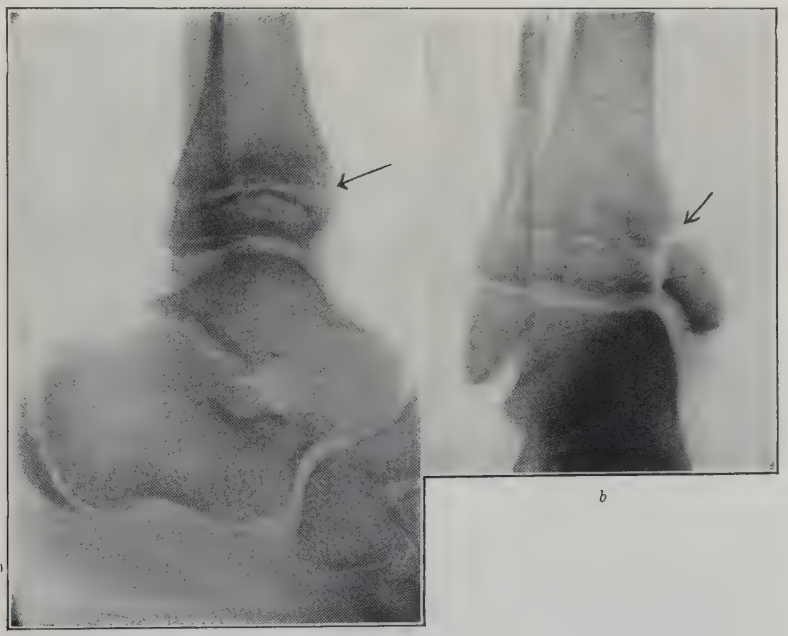
Occasionally a brace will be useful with one or two side uprights to below the knee, attached either to the shoe or to a steel sole plate within the shoe, and with an ankle-joint and suitable strap for holding the ankle.

The exact care of any case following an ankle-joint fracture will be determined by the conditions peculiar to the particular case.

In general it may be said that early replacement of the fracture fragments, early active but guarded movements, early massage, prolonged freedom

Fig. 1297.—Fracture of the lower epiphysis of the tibia close to shaft, and of the lower fibular epiphysis with displacement of the foot inward.

Fig. 1928.—Fracture of the lower tibial epiphysis extending up into the inner edge of the diaphysis of the tibia. A starting of the lower fibular epiphysis.



a *b*

Fig. 1299.—Fracture of the lower tibial epiphysis and damage to the epiphysis further outward: *a*, Lateral, and *b*, anteroposterior views.

from complete weight bearing, protected weight bearing when once begun, support in the instep as a preventive measure—all these measures will conduce to a satisfactory and normal return to active full function of the ankle and foot.

Fig. 1300.—A fracture of the lower tibial epiphysis with displacement slightly upward.

Fig. 1301.—A fracture of the lower tibial epiphysis a little within the longitudinal line of the diaphysis of the tibia.

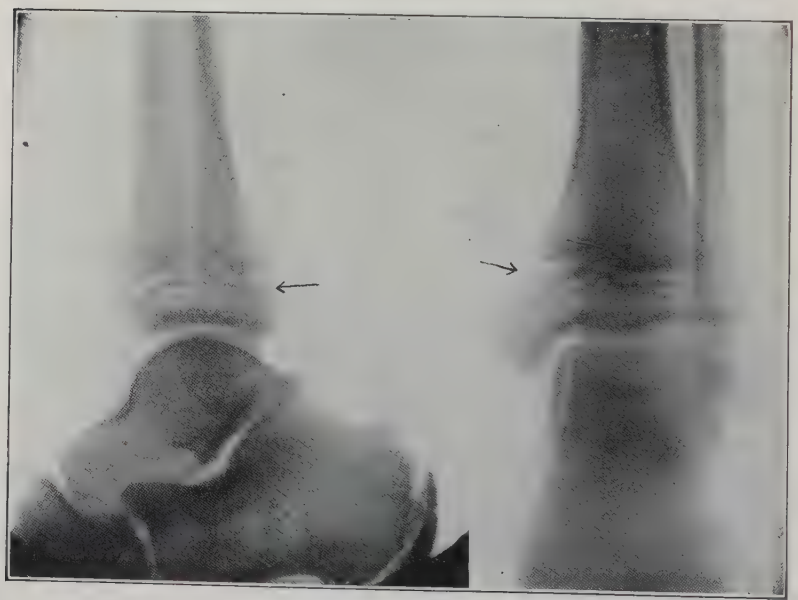


Fig. 1302.—A starting of the lower tibial epiphysis. Note the increased spacing in the epiphyseal line.

Prognosis and Results.—In young adults there should be no deformity and almost no permanent disability. In adults there may be some stiffness for a time. If the *lateral deformity* has not been completely corrected a traumatic pronation of the foot will result. The longitudinal arch of the

foot should be supported always by a suitable pad under the instep for at least six months following this fracture, whether there is deformity or not.

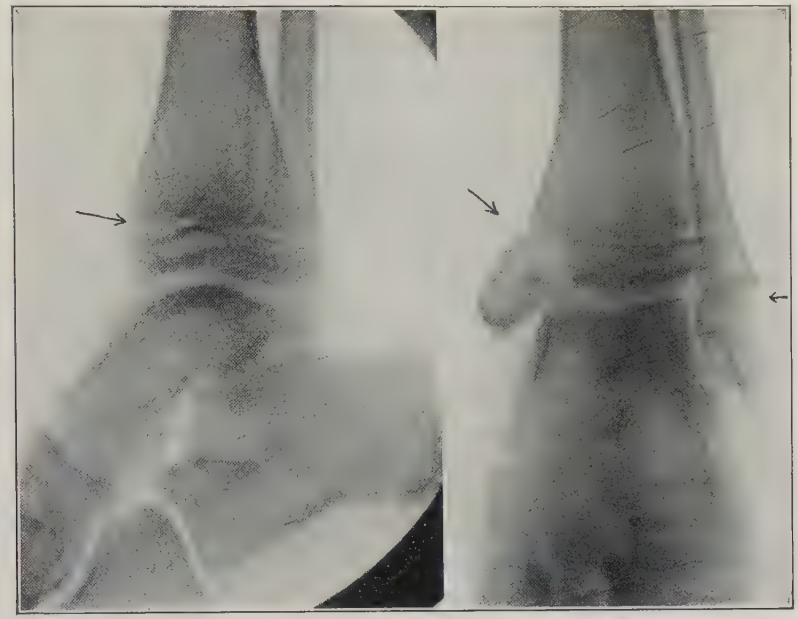


Fig. 1303.—Lateral and anteroposterior views. Note oblique fracture from before backward of epiphysis at its inner side and starting of the epiphysis of the fibula, also a starting of the lower tibial epiphysis.

Fig. 1304.—Fracture of the outer portion of the inferior tibial epiphysis. Note also change in outline of the anterior portion of epiphyseal line indicated by the arrow.

If there is deformity it will relieve the pain. An insole of leather with a pad stitched to it for support to the arch of the foot is often of great service.

If there is no pain or deformity, it will strengthen the foot until walking is easy again, and will prevent deformity appearing. If the *anteroposterior deformity* has not been corrected, pain may be experienced upon using the foot. The foot is shortened and dorsal flexion is much hindered, so that the gait is decidedly impaired. The patient will walk with a more or less stiff ankle. In those cases in which there is great deformity associated with extensive laceration of the soft parts, the foot and ankle may for many weeks subsequent to union be painful, stiff, and swollen. Pain, stiffness, and swelling increase with the age of the patient, *i. e.*, the younger the patient the less discomfort will there be following this fracture.

Open Pott's Fracture (Fig. 1263).—The ankle-joint is involved. Two things are to be considered in deciding upon the treatment of the injury—the extent of the laceration of the soft parts and the amount of injury to the bones. If the crushing and laceration is great with rupture of large blood-vessels so that the foot is useless, amputation is indicated. Amputation may be indicated in two other instances, even with less damage to soft parts than in a younger person—in the presence of old age and sepsis. The compound wound, including bone and soft parts, is to be treated as is indicated in the section on Compound Fractures (p. 889). If the laceration is not great, and any existing dislocation can be reduced, it should be reduced without excision, proper drainage being provided, both anteriorly and posteriorly, to the joint, and not drainage of the joint. If the laceration is not great and reduction of the deformity is impossible, then either partial or complete excision should be done. If there is great injury to bone, whether the dislocation can or cannot be reduced, all fragments should be replaced and only those removed whose loss would not militate against a stable ankle-joint.

A partial or complete excision should be done only in comminuted fractures of the joint surface in adults in which it is obvious that a stiff ankle-joint must follow union. In every open Pott's fracture, no matter how small the wound of the soft parts, in order to insure an aseptic wound it should be enlarged sufficiently for thorough cleansing with antiseptic solutions in every part (p. 889). Extreme conservatism should characterize the treatment of recent open Pott's fracture. In the large majority of cases treated upon the conservative or expectant plan a useful ankle-joint and foot will result. The older the adult patient is, the more radical must be the treatment.

CHAPTER XIX

FRACTURES OF THE BONES OF THE FOOT

Fracture of the astragalus is caused by a blow on the sole of the foot, as in a fall from a height (Fig. 1305). Fracture of the os calcis is often present in the same foot with fracture of the astragalus. The ankle-joint may or may not be involved. The diagnosis is difficult without the use of the Roentgen ray. Crepitus may be elicited. Great swelling may appear in the region of the fracture.

It is highly probable that many cases of sprained ankle have been cases of fracture of the astragalus. If there is no displacement, treatment will consist in immobilizing the ankle-joint with the foot held at a right angle with the leg. As soon as the swelling has begun to subside massage may be used to advantage and convalescence be thus hastened. The most

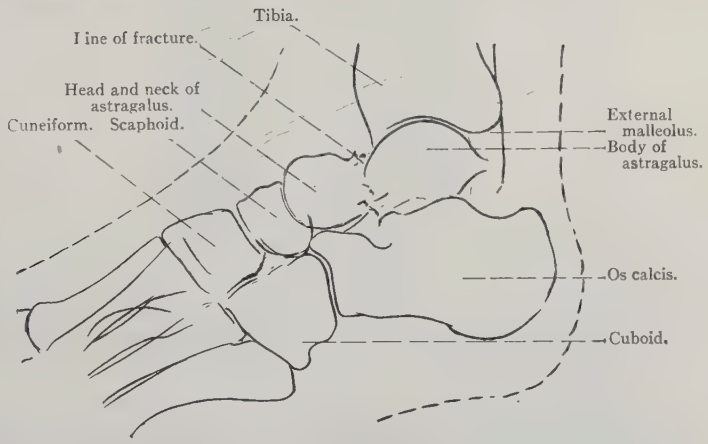


Fig. 1305.—Fracture of the neck of the astragalus (x-ray tracing).

satisfactory dressing is a plaster-of-Paris splint extending from the toes to below the knee, applied and immediately split open, so as to form a removable splint. This may be taken off for massage and passive motion. Recovery takes place with fair movement at the ankle-joint, so that after from two months and a half to three months the patient can walk without support. After this time complete recovery is slow. More or less stiffness and pain may exist for four or six months after the accident.

Fracture of the Os Calcis.—The os calcis is fractured by a fall on the sole of the foot, as well as by a powerful contraction of the gastrocnemius muscle and strong tension upon the tendo achillis. The os calcis is rarely fractured in children because the bone is largely cartilaginous and the foot is much more elastic than in adults. This fracture is more common in men

than in women. It may be crushed, fractured transversely or longitudinally, or a piece may be torn off from its posterior portion near the insertion of the

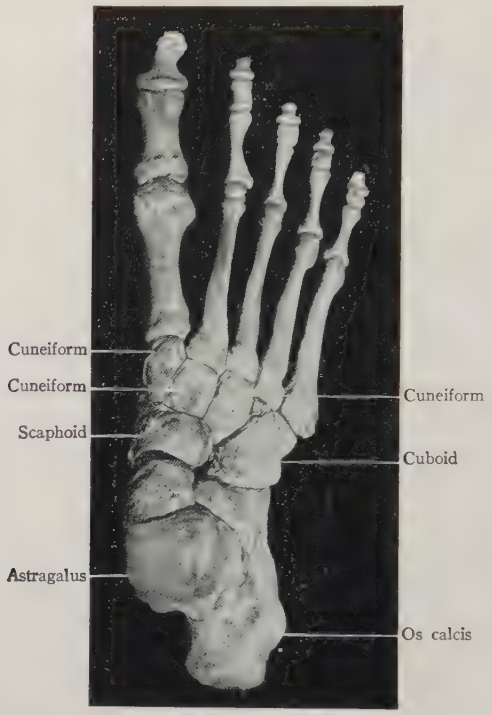


Fig. 1306.—Dorsal view of bones of the foot. Tarsus, metatarsus, and phalanges.

tendo achillis (see Fig. 1317). The fracture lines will vary, but may be linear or comminuted, entering the calcaneo-astragaloid joint or not, with or without displacement of the fragments, and with or without disturbance of the

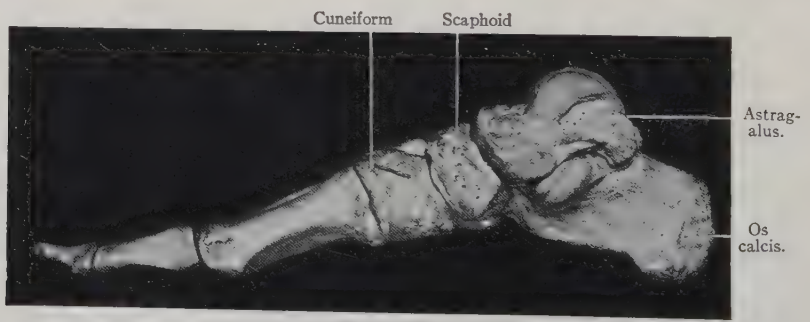


Fig. 1307.—Lateral view of foot showing longitudinal arch of foot. Note relation of individual bones on inner side of foot.

arch of the foot, at least that part of the arch into which the os calcis enters (Cahill). The symptoms of fracture will be the usual ones of crepitus, swelling, pain, and abnormal mobility. The heel is seen, by comparison with

its uninjured fellow, to be enlarged, broadened. The malleoli approximate to the ground. This fracture is sometimes associated with fracture of the astragalus (Fig. 1323).

A Roentgen ray should be taken in both lateral, anteroposterior, and plantar views, otherwise fracture lines may be overlooked and missed. The displacement found at open operation is often greater than the Roentgen films indicate. Many of these fractures are wrongly diagnosed as sprain of the ankle or foot. Early treatment along the lines specified in this section will give good results. Treatment delayed or deferred is followed by less satisfaction. Hence the very great importance of accurate immediate recognition of the fracture.

Fig. 1308.—An *x*-ray of the bones of the normal adult ankle and part of tarsus. Lateral view.

Straus has contributed a useful method of treating recent fracture of the os calcis. The posterior fragment having been driven up and held up by impaction of fragments and by the muscles of the tendo achillis, Straus' operation is as follows:

Under a general anesthetic with the patient in the Hawley table so as to be able to secure countertraction, tenotomy of the tendo achillis is done. A Steinman pin, in two parts, is introduced in front of the tendo achillis, and above the os calcis traction is made in the Steinman caliper. Any impaction is broken up, the foot is moulded into shape with the aid of the V-shaped block for upward pressure in the middle of the sole of the foot.

A plaster-of-Paris splint is applied after the moulding is completed, while the foot is held in inversion, its anterior and posterior portions pulled down-

ward by traction. The pin is removed, the wounds on either side of the heel touched with tincture of iodin and dressed with an occlusive dry gauze dressing. The plaster splint is left *in situ* four weeks. Weight bearing is

Fig. 1309.—Fracture of the astragalus. Patient fell 10 feet to ground, September, 1900. "Sprained ankle." *x*-Ray, fracture of neck of right astragalus.

March, 1901. Bad result. Useless foot. Partial ankylosis. Partial astragalectomy (Brooks).

May, 1905. Foot slightly inverted, longitudinal arch raised, no lateral motion, no flexion, 10 degrees of extension. Painful foot. Bad result (Cabot, Binney).

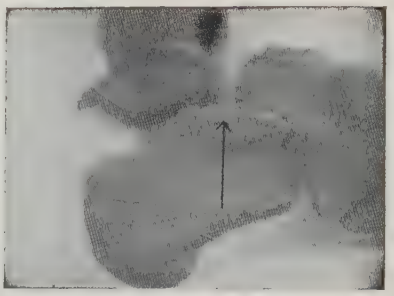


Fig. 1310.—Fracture of astragalus. Fracture due to direct violence, from heavy bar falling on foot, May, 1904. Plaster-of-Paris bandage.

July 4th. Trendelenburg osteotomy.

May, 1905. Painful foot. Forward displacement of foot on leg. Exaggerated longitudinal arch. Deformity not wholly corrected by operation. Marked inversion. Flexion good. Extension limited. Lateral motions limited. Bad result (Cabot, Binney).

allowed gradually after ten weeks. An arch support and cane aid convalescence.

The *treatment* of os calcis fracture will be either: (1) simple fixation of the part without an attempt at reduction of fragments, (2) attempted re-

Fig. 1311.—Fracture of astragalus. Foot run over by heavy team, February, 1902. Treated by natural bone-setter. *x*-Ray shows fracture of neck of astragalus. Operation advised and refused.

September, 1905. Painful foot. Much inversion, large bony fragment on dorsum (head of astragalus). Flexion fair. Extension poor. No lateral motion. Foot very flat. Bad result (Cabot, Binney).

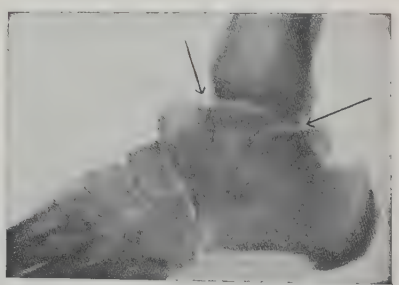


Fig. 1312.—Fracture of astragalus. *x*-Ray shows impaction of astragalus, especially in central portion, with lowering of ankle-joint (Cabot, Binney).

duction of fragments, or (3) an operative procedure. The immobilization of the foot at the angle that will best hold the fragments approximately in apposition is desirable. Complete plantar flexion of the foot may be needed to bring the fragments well into position. The pull upon the tendo achillis

is in this position removed from the posterior fragment. If the fragments cannot be reduced, exposure of them may be wise by incision. Excision of certain portions or retention of fragments by a nail or screw or plate may be helpful. If it is apparent at the outset that a displaced fragment will cause trouble, as when a fragment is displaced into the sole of the foot, it is best to remove this fragment at once through a lateral incision. Massage should be instituted early—during the first week. The removable plaster-of-Paris dressing is the best form of splint. After three weeks the splint should be removed, and a close-fitting flannel bandage applied, with small pads under the malleoli and on each side of the tendo achillis. The pads, if applied with considerable pressure, will assist very materially in reducing the swelling and in restoring form to the ankle. It will be about two months before the patient should bear much weight upon the foot. After three to four months walking may be comparatively easy.

In fracture of the os calcis with lateral displacement and with more or less comminution of bone, the fracture may be loosened by manipulation, the calcaneo-astragalar joint may be freed from adhesions by forced motion, any accumulation of bone beneath the external malleolus may be removed, and the lateral displacement of fragments may be forcibly reduced by a blow with a wooden mallet protected by two layers of felt (Cotton). In other words, a lateral impaction may be obtained by the mallet blow which will improve the form of the foot. The bony arch of the foot may be restored and the fragments lifted upward by forcibly flexing the foot over a sharply angulated block or back of a chair. The attempt to restore the position of fragments and the arch of the foot may be facilitated by traction, caliper or sound above os calcis. The tendo achillis may require cutting or lengthening to secure in the forced equinus position complete passivity of the posterior fragment or fragments.

In fractures of the os calcis not involving the subastragalar joint (shearing fractures, rare fractures of the sustentaculum tali, and muscle fractures) the above methods should be employed. When the subastragalar joint is involved in the fracture, and this is the common fracture of the os calcis (see Figs. 1313 and 1319), Allison and Wilson have emphasized the wisdom of a subastragalar arthrodesis in recent fractures. The calcaneo-astragalar joint is approached from the outer side, the tendons displaced backward, the joint is opened, irregularities of broken bone removed, the cartilage of the joint completely taken away, and the contiguous surfaces of the astragalus and os calcis are carefully fitted and adapted to each other. The retracted tendons are replaced. The wound is closed in layers without drainage. The foot is completely immobilized. Weight bearing is permitted in about six weeks. Protected locomotion is allowed in about eight weeks.

Fusion, an ankylosis, occurs between the astragalus and the os calcis.

The functional return of the usefulness of the foot and ankle as a weight-bearing and locomotive mechanism is very considerably hastened by this treatment. Wilson's results and the results of those who have employed this method are so uniformly good as to recommend it.

Subastragalar arthrodesis for recent fracture of the os calcis entering the subastragalar joint is a constructive operative procedure.

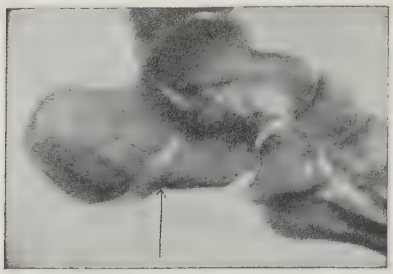


Fig. 1313.—Fracture of the os calcis. Man, forty years, fell 10 feet, striking squarely upon both heels, on the ground.

x-Ray shows fracture of the os calcis of the large heel fragment type.

This is a favorable case for tenotomy of the tendo achillis and reduction of the posterior fragment, with restoration of the arch and arthrodesis of the subastragalar joint (Cabot, Binney).

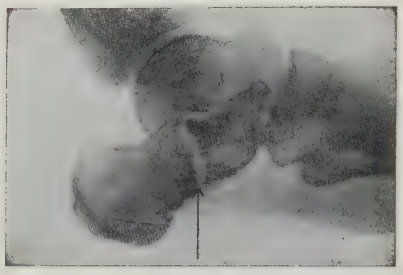


Fig. 1314.—Fracture of the os calcis. This patient, a man, fell 15 feet on to frozen ground, striking upon both feet, in February, 1899. Right heel showed abnormal mobility and crepitus over the os calcis. *x*-Ray shows comminuted fracture with large heel fragment. Treated with pillow splint; plaster-of-Paris bandage.

May, 1895. Has some pain through ankle-joint. Always wears an insole. Is considerably hindered about his work. Examination, right foot: Considerable bony overgrowth beneath external malleolus. Motions: No flexion beyond right angle. No adduction. Very little abduction. Fair extension. Good position. Longitudinal arch, fair. Classed as fair result. Calcaneo-astragalar joint involved (Cabot, Binney).

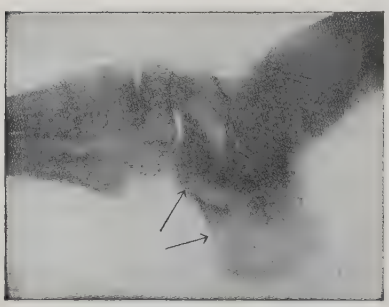


Fig. 1315.—Fracture of the os calcis. Man, twenty-six, fell from moving car, striking left foot against tie. In May, 1890, *x*-ray shows fracture of os calcis, large heel fragment type, with tendency of posterior fragment to be drawn upward. Plaster-of-Paris bandage.

June, 1905. Reports returned to work after three and a half months. Very little trouble at any time. Foot becomes tired after long day's work. Present condition, slight fulness beneath external malleolus. Extension good. Flexion slightly limited. Very little lateral motion. No "flat-foot." Classified as good result (Cabot, Binney).

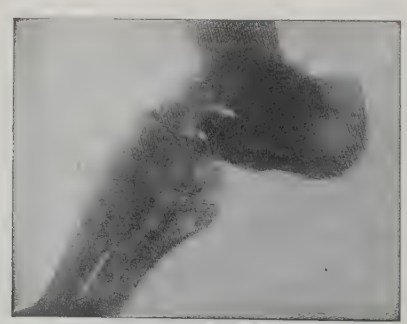


Fig. 1316.—Fracture of the os calcis. Shows same foot as Fig. 1315, six years after injury. Note great thickening of central portion of os calcis with fusion of astragalocalcaneal joint (Cabot, Binney).

In most fractures entering a joint attempts are made to secure movement in the involved joint. In these common and disabling fractures of the os calcis the joint must be ankylosed. The disabling osteo-arthritis of the involved joint is avoided and the movement at this joint is sacrificed to the

always developed compensatory movement at certain of the other tarsal joints.

It is usually the case after fracture of the os calcis and also after fracture of the astragalus, in which complete reduction has not been secured, that there is considerable disturbance of the normal mechanism of the foot. A

Fig. 1317.—Fracture of the os calcis. A good example of small heel fragment type of fracture. Caused by slipping while getting on a street car, apparently by sudden contraction of calf muscles. Operation refused. Result unknown (Cabot, Binney).

Fig. 1318.—Fracture of the os calcis. Shows another type of comminuted fracture of the anterior half of the os calcis. Note great flattening of longitudinal arch. Result unrecorded (Cabot, Binney).

traumatic flat-foot results from the accident. This can be greatly relieved by the introduction into the shoe of a leather pad to raise the instep and take the strain off the injured part. The patient may find that for a period of six months or more the wearing of this pad is a great support and comfort. If the use of a flat-foot support does not relieve these old cases an

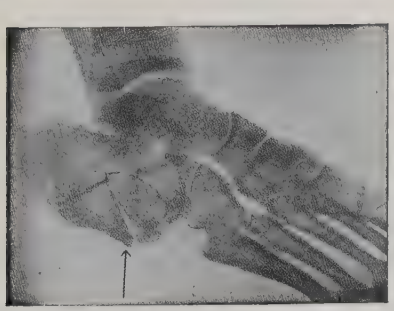


Fig. 1319.—Fracture of the os calcis (right). The calcaneo-astragalar joint is involved in the fracture (Cabot, Binney).

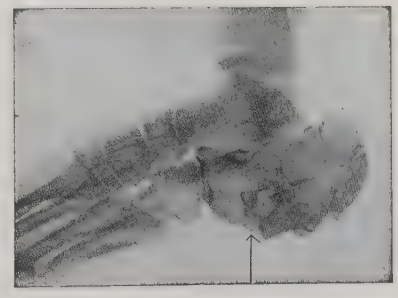


Fig. 1320.—Fracture of os calcis (left).

osteotomy must be considered as helping to secure a restoration of the arch. The hot-air baking is very satisfactory for the relief of the pain and stiffness felt throughout the ankle and foot. The hot-air treatment, combined with massage, helps to hasten convalescence. This treatment should be used once daily until the pain in the foot has disappeared.

If there is a dislocation of a portion of the astragalus, either the fragment must be accurately reduced or, if this is impossible, the fragment should be removed.

If there is a compound fracture of the astragalus, and the time elapsed since the injury is several hours, it will be unwise to assume that the wound can be completely cleansed. Excision of the fragment or of the entire astragalus will be the most conservative treatment. At the same time thor-

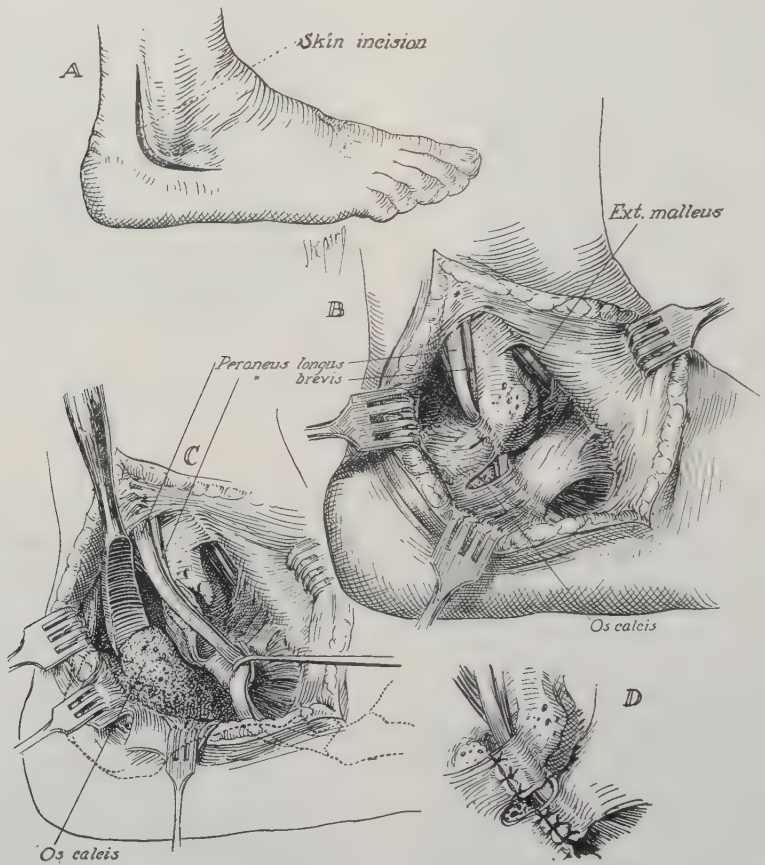


Fig. 1321.—Operation for removal of bone and callus behind external malleolus (Magnuson). The same incision and exposure serve for the approach to the subastragalar joint in the operation of subastragalar arthrodesis advocated strongly by Wilson.

ough posterior drainage should be provided by a rubber tube for the cavity left after excision.

Following a fall a child may complain of lameness and foot pain, or there may be no complaint, the child purposely concealing evidences of discomfort. If the foot of such a child is carefully examined there may be found a tender area over the os calcis. This tenderness will often correspond to a linear fracture, without displacement. If this is allowed to go unrecognized and without treatment a chronic difficulty may result which will be

painful and slow in healing. Suitable protection to such an injury will cause it to quickly disappear.

Operation for Correction of Deformity Following Fracture of the Os Calcis.—The indications for this operation, as outlined by Magnuson, are as follows:

Fracture through the body of the os calcis with the posterior fragment somewhat everted and carried upward.

Where there is a callous formation behind and underneath the external malleolus, with pronation of the foot and pain in the arch, due to faulty weight bearing.

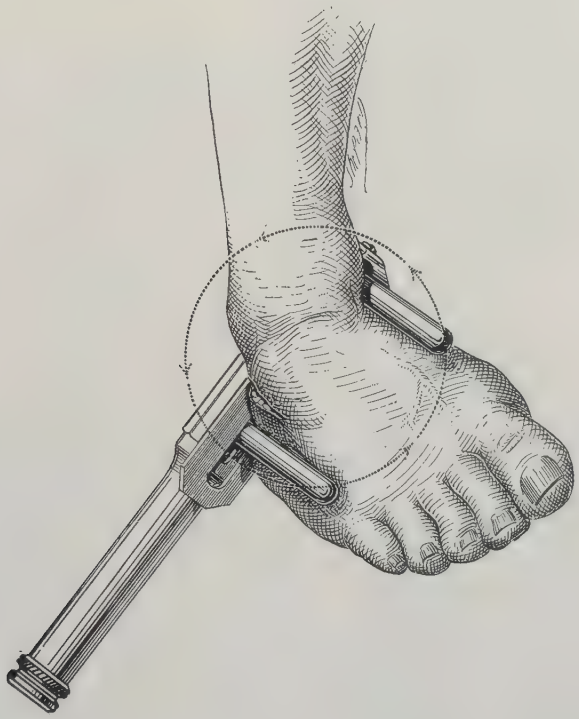


Fig. 1322.—Employment of wrench in correcting eversion of foot following fracture of os calcis (Magnuson.

If there has been a fracture into the astragalocalcaneal joint, with callous formation and roughening in this joint, the operation gives very little relief except in so far as the pain behind and underneath the external malleolus is concerned, which is purely due to pressure on the tendons running behind the external malleolus. See Allison's suggestion and method under these conditions (p. 719). The operation of itself relieves this condition only, the strong eversion of the foot with the wrench moving the os calcis over on the astragalus and inverting the foot and maintaining it in inversion until the external ligaments of the ankle-joint are healed and the internal contracted, is the thing, of course, which gives relief to the faulty weight bearing.

The operator must have sufficient confidence in his judgment to carry this eversion far enough if the operation as a whole is to be successful; and

it is true that one feels sometimes that he is tearing the whole foot off with the amount of pressure that must be used.

Especial attention should be called to the placing of the two arms of the wrench. The distal arm is to be placed underneath the internal malleolus, against the inner surface of the astragalus, and the proximal arm of the

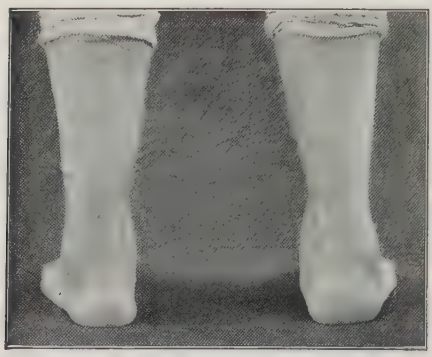


Fig. 1323.—Posterior view of fracture of right os calcis and of left astragalus. Deformity. Note fulness each side of the tendo achillis (see *x*-ray tracing, Fig. 1305).

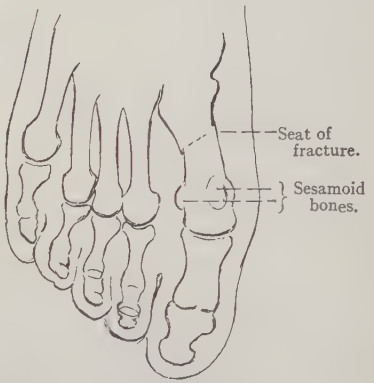


Fig. 1324.—Fracture across the first metatarsal of the right foot (*x*-ray tracing).

Fig. 1325.—Fracture of the sesamoid bone of the metatarsophalangeal joint of the left foot. An unusual injury, but to be reckoned with when persistent pain is present after an injury in this region. There is a sesamoid bone on each side of the head of the first metatarsal—one in each tendon of insertion of the flexor brevis hallucis (C. Painter).

Fig. 1326.—Transverse fracture of the fifth metatarsal bone.

wrench against the outer and lower margin of the os calcis. These two points must be maintained with one hand while the operator strongly inverts the foot by the use of the other on the handle of the wrench, and the inversion must be carried out until the astragalocalcaneal joint is everted and strong inversion can be maintained after the wrench is taken off.

Open fracture of the astragalus and os calcis, if treated antiseptically, recovers with a useful ankle and foot even though the ankle-joint is ankylosed. The mediotarsal joint becomes more flexible than it ordinarily is. The loss of motion at the ankle-joint is compensated for by the mediotarsal joint motion, and the individual may walk with hardly a perceptible limp. Removal by operation of the fractured bone is attended by good functional results, and if the bone is much comminuted or dislocated, operation is indicated. A careful study of the results of fracture of the astragalus and of the os calcis, as published by Cabot and Binney and recorded here in *x*-rays (Figs. 1309–1321), will prove helpful.

Fig. 1327.—Note fractures of the sesamoid and the head of the metatarsal bones.

Fracture of the Scaphoid of the Tarsus. Fracture of the Metatarsal Bones.—This fracture of the scaphoid is caused by direct violence. There is evidence to show that indirect violence may cause a fracture of metatarsal bones. The first and fifth bones are the ones most often broken (Fig. 1324). The symptoms are swelling, pain, crepitus, and abnormal mobility. The weight cannot be borne upon the foot without pain. There is never great displacement. In order to avoid trouble in walking, after union has occurred it is wise to make the approximation of the fragments as nearly accurate as possible. A closed or simple fracture is ordinarily uncomplicated. Union

takes place in from three to four weeks. It will be at least from two to four months before the foot can be used without thought of the injury received.

If the fracture is open, repair may be slower than after a closed fracture. If the wound is kept clean and free from infection no complications will arise. If, on the other hand, the wound becomes infected, necrosis of bone, abscess formation, burrowing of pus, and great swelling of the foot may occur, all of which will greatly delay the healing process. The foot should be immobilized by a lateral molded splint of plaster of Paris. This should be placed upon either the outer or inner side of the ankle, according as the outer or inner metatarsals

Fig. 1328.—Note multiple fractures of the foot.

are broken. The splint should extend from the middle of the calf of the leg to the tips of the toes. It is held in position by a roller bandage of gauze.

Fracture of the Phalanges of the Foot.—These fractures are rather unusual, except from a crush of the foot. They are sometimes open. The same general rules of treatment apply to fractures of these bones as to fractures of the phalanges of the hand. A simple plantar splint of splint wood, padding of the toes, and adhesive-plaster straps will be sufficient to hold the fracture. If the plantar splint covers the entire sole of the foot, it will prove of great comfort. It is sometimes wise to immobilize the ankle-joint by the thin plaster side splint, particularly if there is swelling of the leg and ankle.

CHAPTER XX

THE OPERATIVE TREATMENT OF FRACTURES

In the preceding pages are given acceptable methods of treating the ordinary fractures of civil life by non-operative procedures. In the chapter dealing with each fracture are mentioned conditions under which operation might be indicated. In the following pages are presented

The principles of the non-operative versus the operative methods of fracture treatment.

The qualifications of a surgeon for operative work.

The details of the conduct of an operation.

The methods of direct fixation.

The operative approaches to bones.

The methods of skeletal traction.

Special operations.

A summary of fractures often operated upon.

Fig. 1329.—Fracture of the shaft of humerus in the upper third. This fracture is often impossible to reduce without operative assistance.

Thus here the operative method of treating fractures is presented by itself as a system of treatment independently of the advisability of its being applied to any particular fracture. An important chapter of general surgery.

Principles of the Non-operative and the Operative Methods of Treating Fractures.—There are certain basic principles of the treatment of fractures which are common to all methods, whether these methods are classed as operative or non-operative. They are:

1. Perfect anatomical reposition, other things being equal, should result in perfect function.

2. Moderate restitution of form, poor anatomical replacement, lead to poor function.

3. A certain variation from the normal anatomical reposition may result in perfect function.

The separation or displacement of the fragments of a fracture are caused by:

1. The force which broke the bone, the fragments will be pushed away from each other, displaced.

Fig. 1330.—Fracture of the surgical neck of the humerus with displacement of both fragments. Reduced most intelligently if assisted by an incision.

Fig. 1331.—Fracture of the shaft of the humerus in the lower third. Approximation most accurately secured through operation.

2. The weight of the limb will act to carry certain fragments out of line.

3. The contraction of muscles and, most important, the retraction of fascial planes and bands will continue to separate and hold fragments apart.

Fig. 1332.—Fracture at the epiphyseal line of the lower end of the humerus. Reduction may be very much facilitated by an incision and direct digital pressure and instrumental leverage on the fragment of the epiphysis.

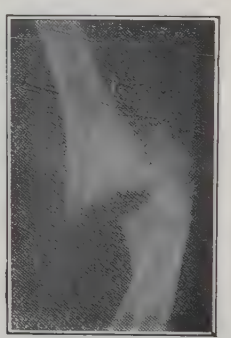


Fig. 1333.—Fracture at epiphyseal line of lower end of the humerus. Lateral view of Fig. 1332.

The **factors underlying the non-operative or traction treatment** are briefly as follows:

(*a*) A longitudinally extending force applied to the distal fragment which will overcome the shortening and possibly correct the lateral displacement and angulation of the fragments.

(*b*) The extending force must be free and unhindered. If the limb being extended rests on the bed or is held more or less rigidly in a splint, perhaps in a long outside splint if it is a fracture of the shaft of the femur,

Fig. 1334.—Fracture of both bones of the fore-arm, with union of the radius and non-union of the ulnar. Operation is indicated to secure union in good position.

Fig. 1335.—Fracture of the upper third of the shaft of the femur. Alignment is imperfect.

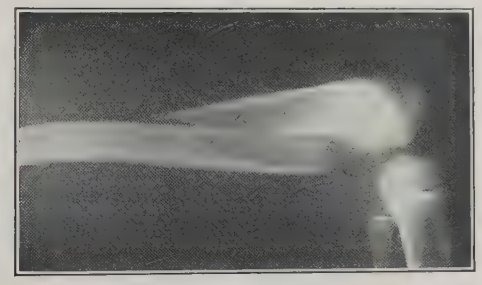


Fig. 1336.—Oblique fracture of the lower third of the femur.

Fig. 1337.—Fracture of the shaft of the femur above the condyles.

so much friction will exist between the limb, splint, and bed that the traction force will be dissipated in overcoming this friction—much extending power on the fracture will be lost.

(*c*) The traction force must be applied early after the fracture and must be adequate to at once effect reduction if the traction force is to be properly used.

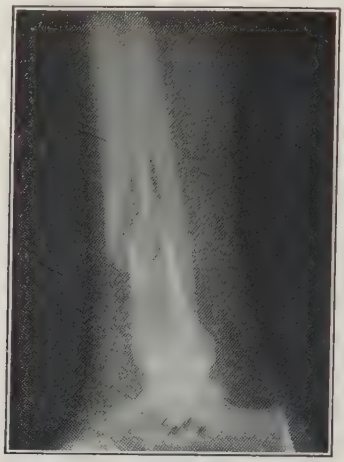


Fig. 1338.—Oblique fracture of the tibia.

Fig. 1339.—Fracture of both bones of the leg

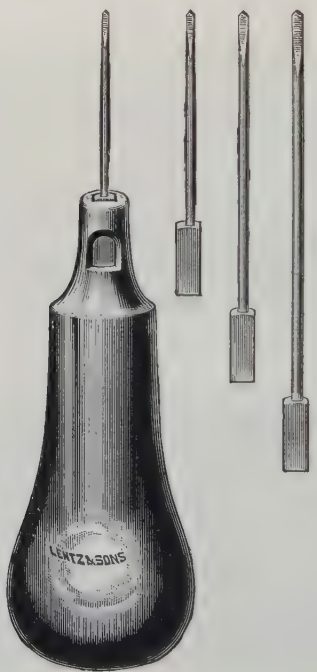


Fig. 1340.—A simple drill for bone.

(*d*) The tracting force must be so applied that massage and passive and active movements in the joints concerned may be practised at a very early period in treatment before the longitudinal pull is removed or completed.

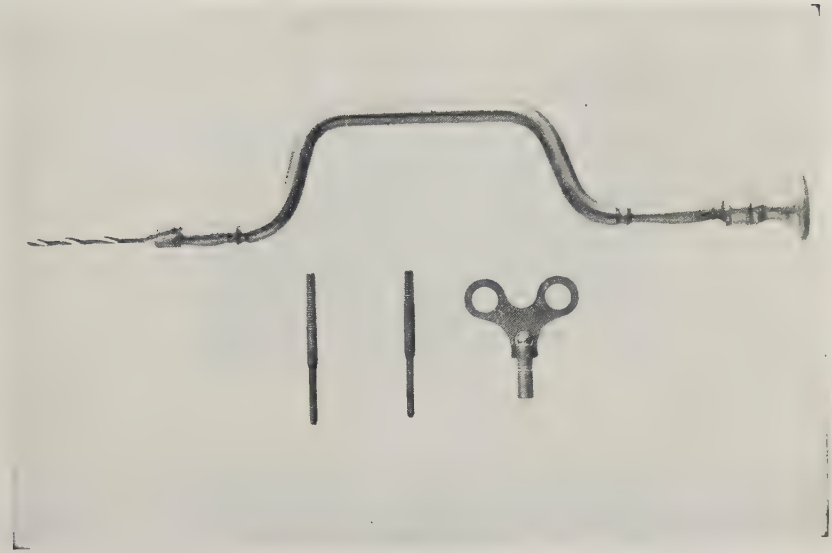


Fig 1341.—Bone-drill in brace. Bone-screws and clock-key, the latter fitting the squared ends of the screws and also used to tighten the bone-clamp.

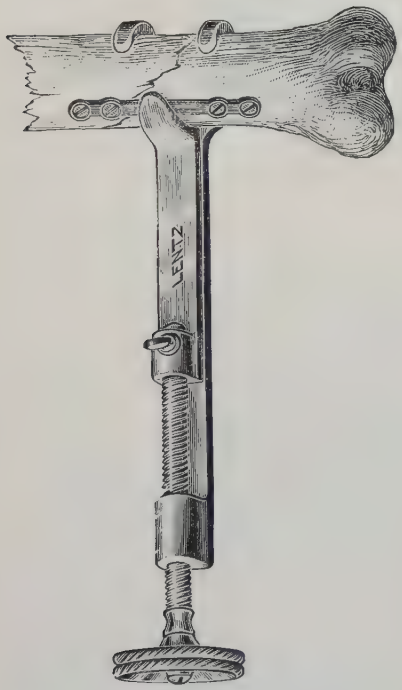
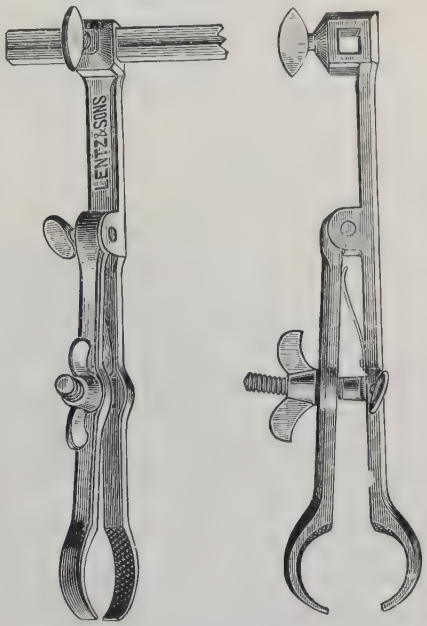


Fig. 1342.—Lowman's clamp for holding the shaft of bone. Note bone plate *in situ*.



Figs. 1343, 1344.—Martin's bone clamp for holding bone fragments in alignment.

Such application of the tracting force will allow joint motion later than massage methods, but earlier than the older plaster-fixation methods.

Manipulations of fragments to overcome displacements and irregularities which simple traction will not eradicate may cause serious harm by getting muscle bundles and fascia and periosteal shreds and strings caught in

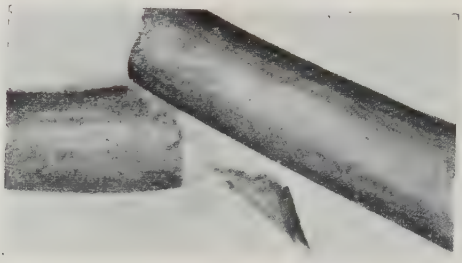


Fig. 1345.—Within one week of accident.

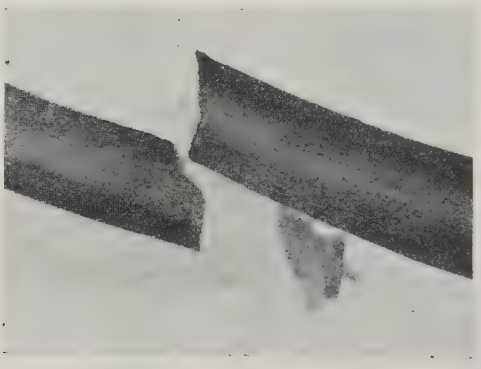


Fig. 1346.—Appearance after two weeks' extension.

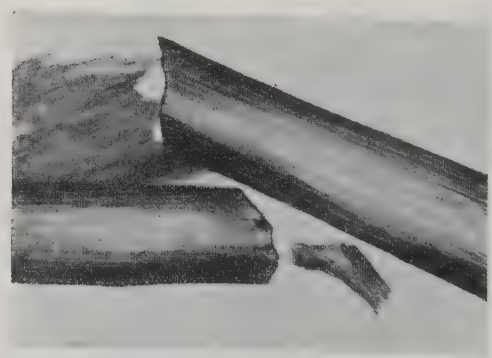


Fig. 1347.—Appearance after three months.

Figs. 1345–1347.—Three roentgenograms of a fracture of the femur treated by traction in a man forty-two years old. These three records illustrate among other things the liability of the femur to secondary displacement under inefficient traction and countertraction. (From Hey-Groves.)

between the fragments; by so disturbing, traumatizing the tissues at the seat of the fracture, including the bone ends, as to seriously hinder the reparative processes. The *rotation of fragments* on long axes may require

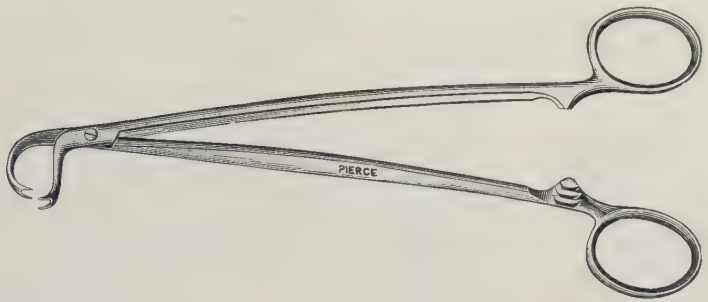


Fig. 1348.—Moynihan towel clamp, essential in holding sterile towel either side of operative field. Two dozen needed for a long thigh wound in approach to femoral shaft.

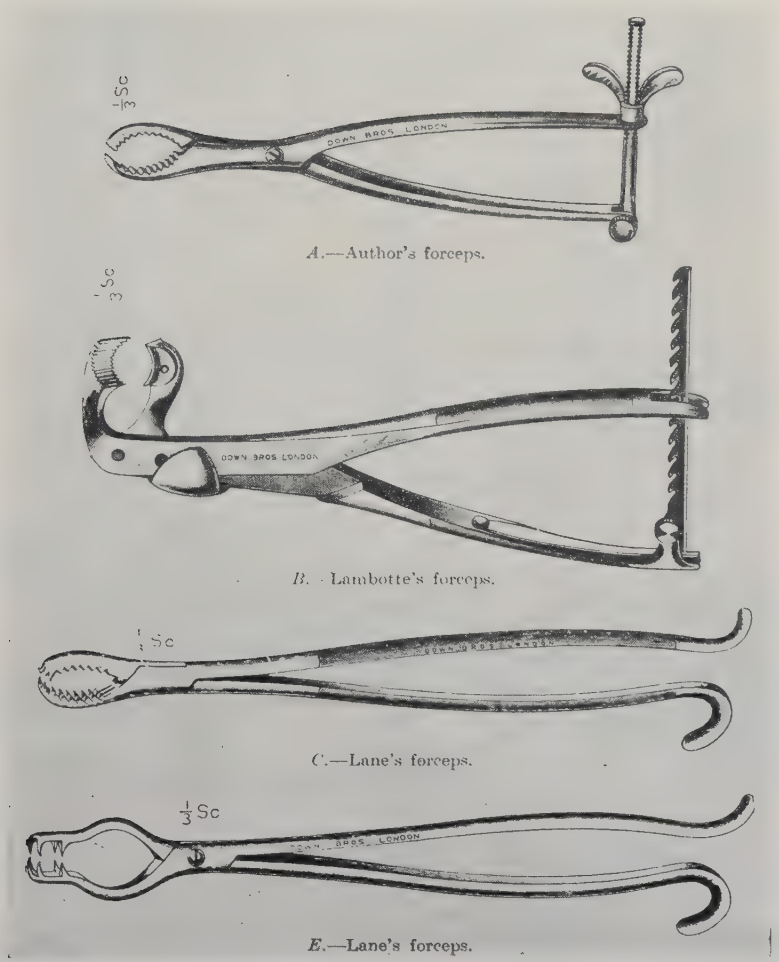


Fig. 1349.—Types of bone-holding instruments. (From Hey-Groves Modern Methods of Treating Fractures, p. 153.)

more than an immediate primary correction. Perfect maintenance of the corrected position should be sought. *Angulation* will need correction by changed position of the limb and by the appropriate direction of pull on the bone. This direction of the pull may need to be different from the simple straight longitudinal pull.

It is coming more and more to be clearly understood just what can be ac-

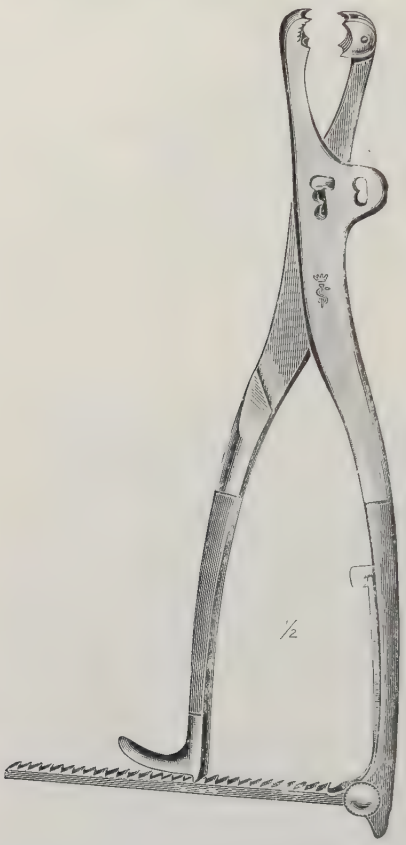


Fig. 1350.—Lambotte's bone-holding forceps.

Fig. 1351.—Stille bone clamp (Sherman).

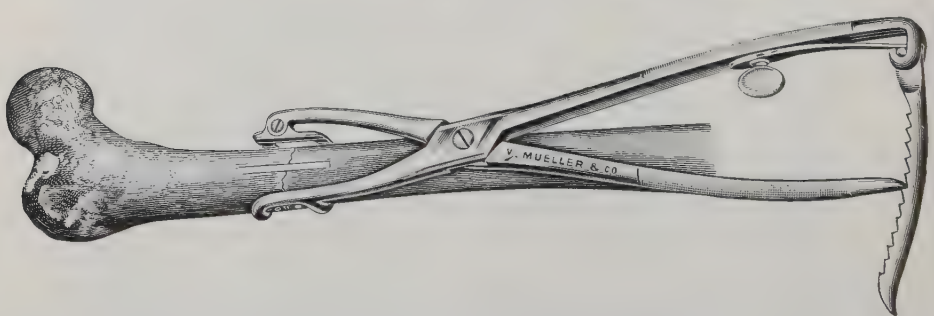


Fig. 1352.—Magnuson's bone-holding clamp. Note the handles of the clamp are parallel to the long axis of the bone. Thus the clamp facilitates the handling of the bone for plastic work.

complished by the traction method of treatment. The Great War demonstrated this on a very large scale and hastened information on this important question. I am speaking now of the ideal application of traction to an

ordinary uncomplicated fracture of a long bone. *Skin traction* is efficient up to a certain point; beyond this skin traction becomes useless and a distinct menace. *Skin traction* with a small weight will steady a limb, but will have

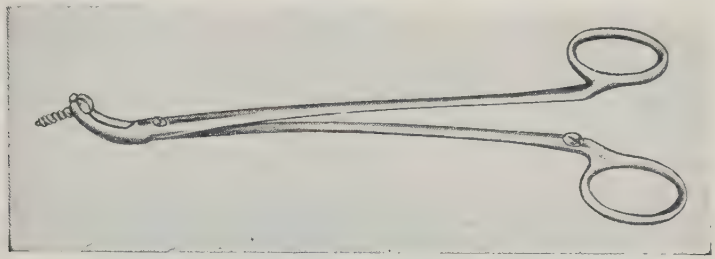


Fig. 1353.—Lane's screw-holding forceps. (From Bickham, Operative Surgery, vol. ii.)

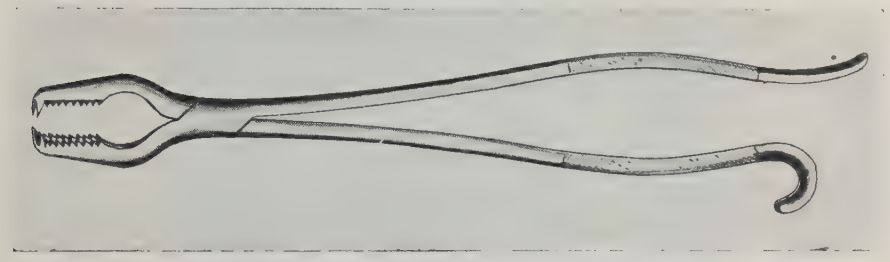


Fig. 1354.—Lane's bone-holding forceps. (From Bickham, Operative Surgery, vol. ii.)

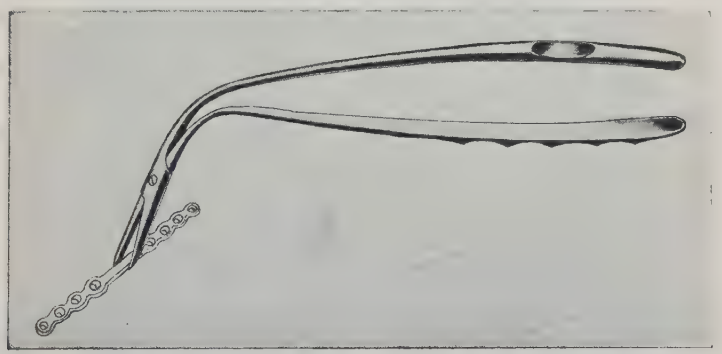


Fig. 1355.—Lane's plate-holding forceps. (From Bickham, Operative Surgery, vol. ii.)

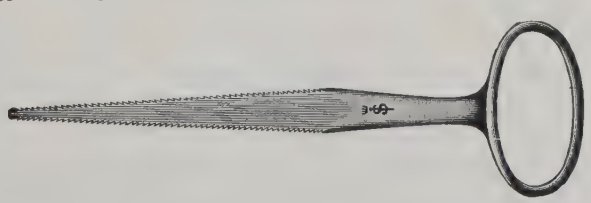


Fig. 1356.—Lane's repositor of fragments, bone extension instrument.

little or no distracting effect on the fracture. *Skin traction* with a heavy weight will affect the position of the bone fragments somewhat, sometimes sufficiently, more often insufficiently, but at the expense of the integrity of the

skin. The adhesive plaster too often will slip just short of accomplishing reduction. The glue traction may be an irritant to the skin, although not usually. A very *heavy weight* applied through the skin traction will not always overcome shortening—it may not be efficient. It excoriates the skin. *Skeletal traction* is available (p. 217). A smaller weight will accomplish more applied directly to the bone, to the distal fragment, through caliper or pin than a much larger weight applied through the skin (about one-third less weight by skeletal traction is needed).

Skeletal traction is efficient in overcoming shortening.

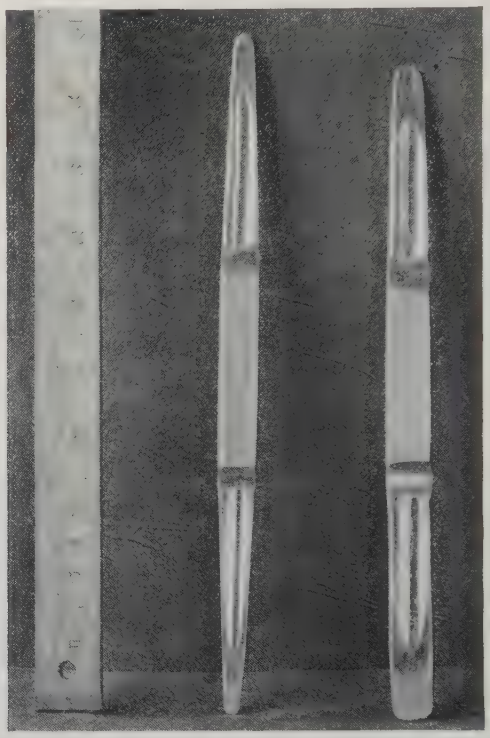


Fig. 1357.—Scudder's levers for safely and accurately replacing displaced bone fragments in the shafts of long bones. Note sizes, roughness at the end for holding, and grooved surfaces for facilitating sliding of fragments.

The maximum accomplishment of traction applied to skin or bone is always secured when it is applied early after the accident causing the fracture. The greatest efficiency is from early application.

We are trying by treatment to overcome in a fracture not only shortening, but lateral and angular displacements.

If apposition of the fracture fragments cannot be secured by traction within a week or ten days combined with manipulation and pressure, then the traction method fails.

The displacement of the fragments of any fracture should at the outset, because of experience, indicate whether there is likelihood of success by non-operative measures.

Moreover, the age of the patient will indicate at once whether the particular case may be successfully treated by traction methods. Most fractures in children under twelve years require only traction methods, non-operative skin traction with manipulation.

Conclusions Regarding Traction Treatment.—Large groups of cases are being treated by ideally applied traction methods. The results in civil practice are coming to be known. The method is efficient.

Its applicability must be carefully chosen. Its conduct must be ideal. The results must be published.

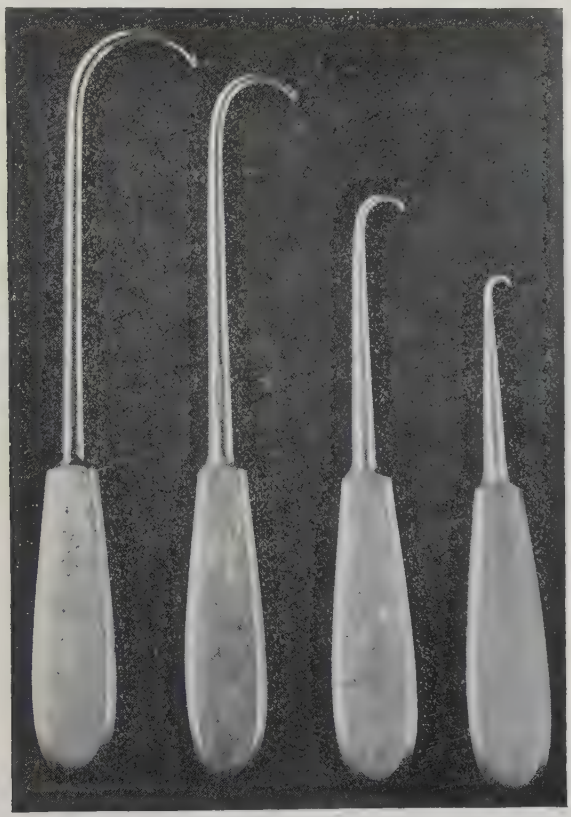


Fig. 1358.—Lambotte-Scudder hooks for manipulating fragments of fractures.

The principles of the operative treatment of fractures are:

1. The direct approach to the broken bone through a wound of the soft parts.

2. The immediate direct application to the bony fragments of traction, countertraction, leverage, manipulation, and pressure.

3. The fixation of replaced fragments by fortunate position, or by absorbable or non-absorbable materials.

4. The early practice of massage and active and passive movements of joints (p. 907).

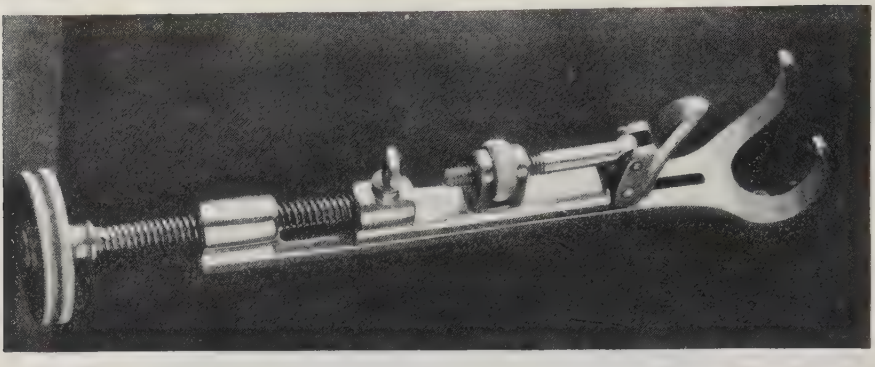


Fig. 1359.—The Lowman-Scudder bone-holding clamp. Note the movable, hence adjustable, third arm of the clamp.

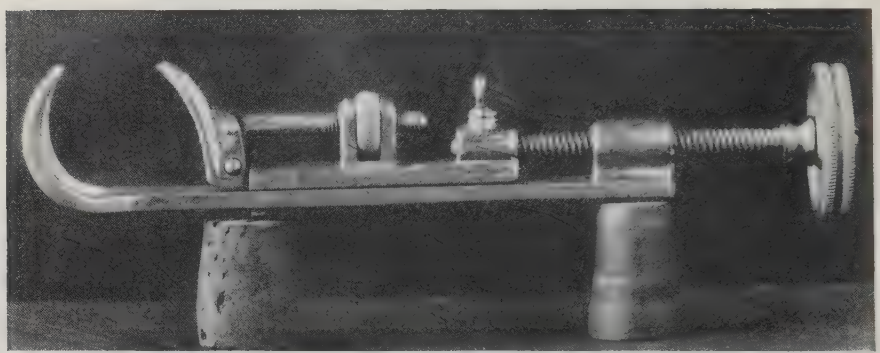


Fig. 1360.—Lowman-Scudder bone clamp, side view. Note screw mechanism for moving third arm of clamp.

Fig. 1361.—Lowman bone and plate holder. Two sizes manufactured.

The greatest success of the operative method depends on its early employment. Its early employment means ease in application, less damage

to soft parts, a less complicated operation, less shock to the patient, less disturbance to the osteogenetic processes, less likelihood of non-union.

The early employment of the operative treatment is fundamental to its greatest success and efficiency.

The results of the operative treatment of closed fractures are being well recorded in increasing numbers. The operative method is a well-established method (p. 748). There are very definite indications for its use.

There are certain fractures which should be treated by operative methods:

(*a*) Those fractures having received early traction treatment with attempted fluoroscopic reduction which remain so unreduced that union is

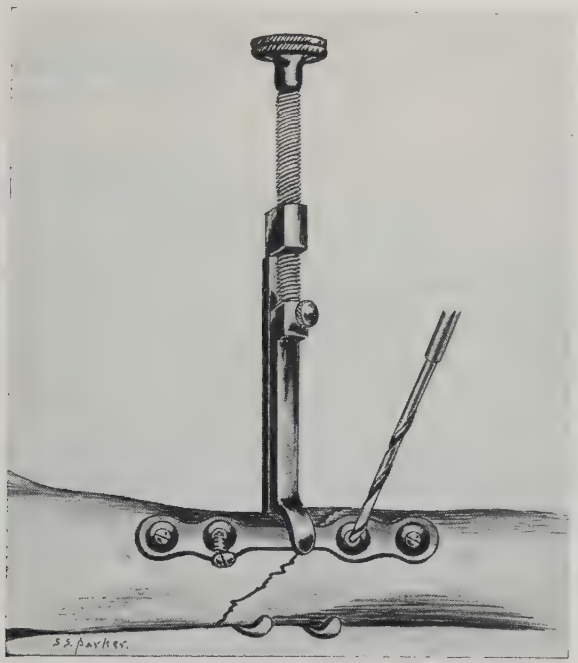


Fig. 1362.—Manner of clamping a Lane plate in contract with the bone during its adjustment. A screw-hole is being drilled; one screw is being placed, and two screws have been driven home. Gerster-Lowman clamp is here employed. (From Bickham, Operative Surgery, vol. ii.)

menaced or that subsequent normal function is unlikely and which can be made anatomically correct. This group of cases will be assembled after one week or ten days of the accident—they are recent fractures.

See remarks on the harm from repeated attempts at reduction with and without fluoroscopic assistance.

(*b*) Cases which cannot be held reduced.

(*c*) Cases which can be assured better function by operation—based on accumulating experience. This group is increasing. In many cases the preliminary try at reduction "is not worth while"—"is unnecessary"—it has been so many times proved impossible.

(*d*) Compound fractures of a certain type.

(*e*) Certain fractures which should have been operated on at the very first, but in which operation has had to be postponed because of an associated septic wound, injured skin from adhesive plaster traction, faulty union from misapplication of the non-operative treatment, non-union from a similar cause.

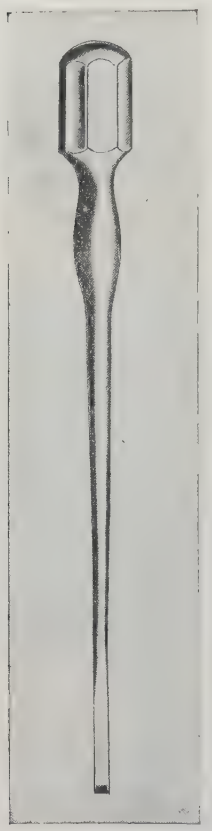


Fig. 1363.—Lane's screw-driver. (From Bickham, Operative Surgery, vol. ii.)

(*f*) Fractures solidly united having persisting sinuses leading to various sequestræ. The sequestra must be removed to insure wound healing (p. 944).

(*g*) Unusual cases in civil life of open fractures with non-union, having an actual loss of substance between the fracture ends, in which a "step cut" or bridge grafting operation is indicated.

At the outset, immediately upon the receipt of the injury, all fractures demand call for with an ever-increasing demand *one* treatment (closed or open) to the exclusion of the other treatment (open or closed).

With the known efficiency and shortcomings of each method of treatment recognized, with the known conditions of any given fracture fully understood, it is possible logically to choose at the outset one method of treatment which may be instituted and carried out consistently to the conclusion of treatment and with the maximum benefit to the individual. I have no patience with those who today oppose either method of treatment. Both methods are efficient and desirable from the outset. Both methods demand the highest surgical acumen and skill.

The operative treatment of fractures stands as a method of treatment to be chosen for what it can positively accomplish. It should not be looked upon merely as a last resource, to be employed when all other methods fail. It is often, and will increasingly be, a first resource. The operation upon a fracture is a major surgical procedure. It is not devoid of risk. It has peculiar difficulties and peculiar dangers. It is followed by ideal results.

There are surgeons who understand thoroughly the expectant non-operative treatment.

There are surgeons who understand thoroughly the operative treatment.

There are surgeons who know equally well the operative and the non-operative treatment.

Each could use the methods of the other on occasion.

Each is liable to carry the trial of his own preferred method too far before admitting defeat.

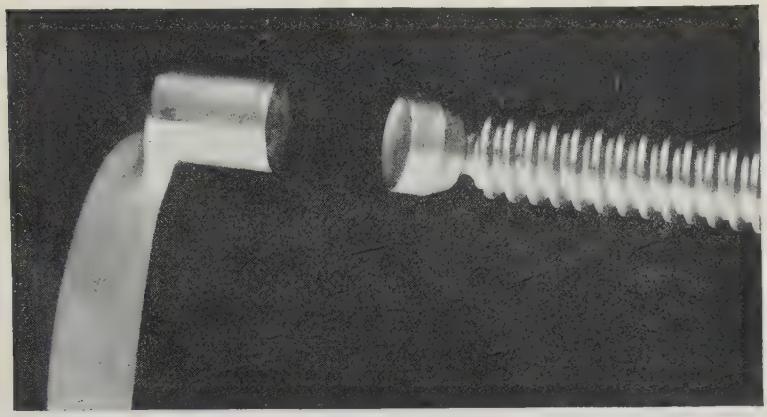


Fig. 1364.—The Scudder lateral pressure clamp. This shows the cup-shaped bearing surfaces, and on the screw side the universal jointed tip for more complete adaptability to irregular surfaces.

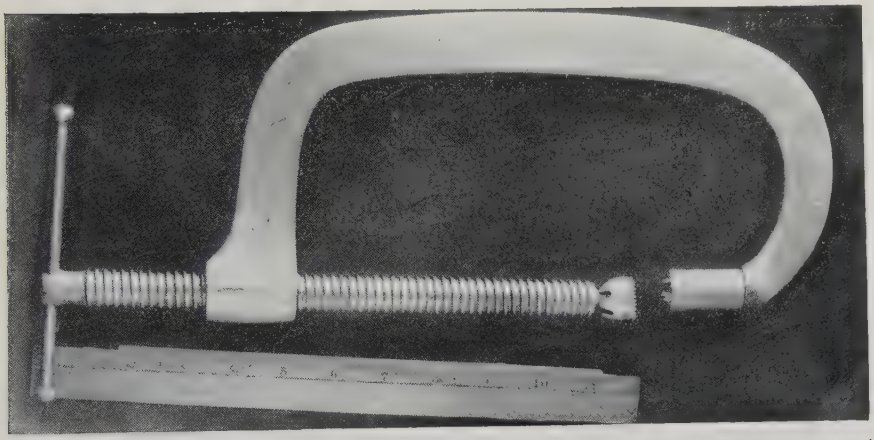


Fig. 1365.—The Scudder lateral pressure clamp. Large size for use on the condyles of the femur and on the lateral masses of the tibia.

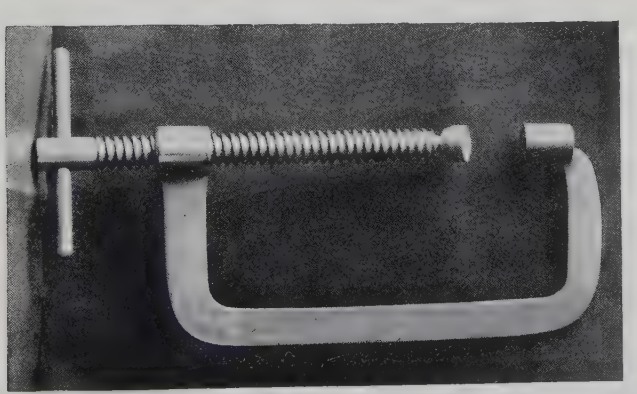


Fig. 1366.—The Scudder lateral pressure clamp. Small size for use on the lower end of the humerus.

The operative enthusiast may not give adequate trial (in time and means employed) to the traction method which might have been successful. The

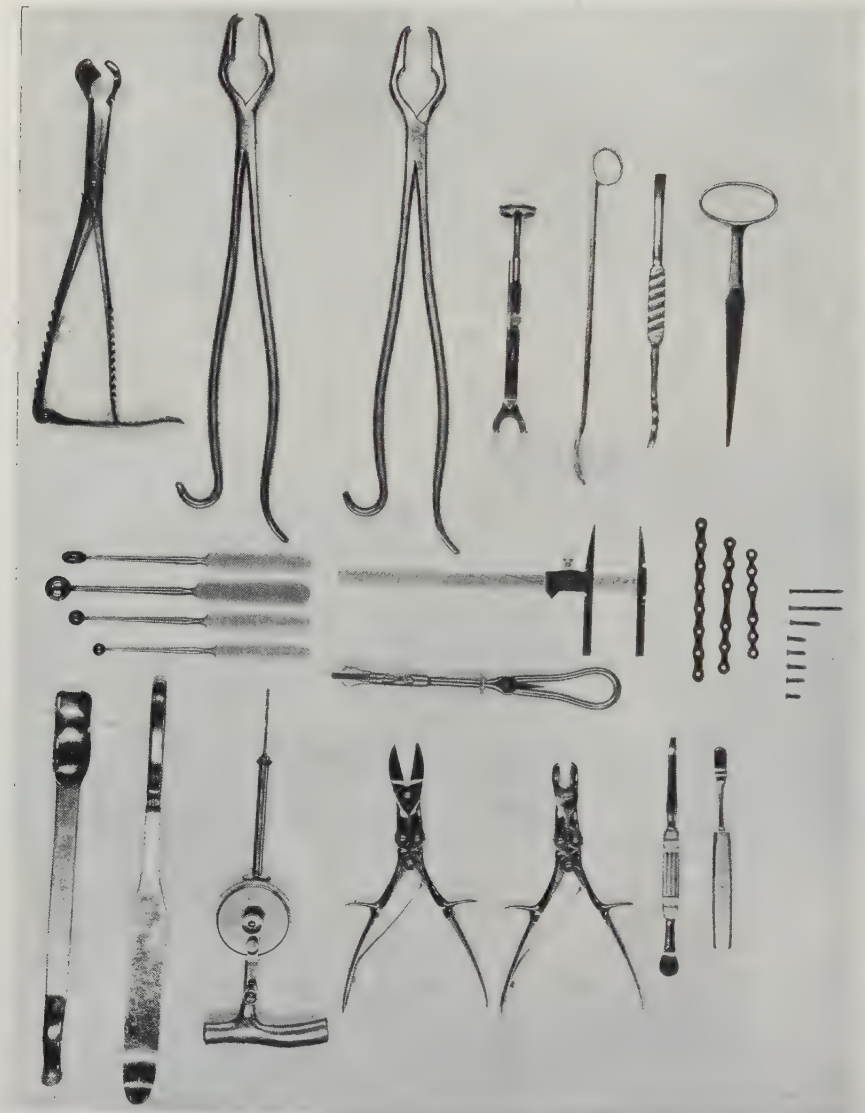


Fig. 1367.—Instruments necessary for operation on fracture of the femur (reading left to right): 1. Sherman-Lambotte bone-holding forceps. 2. Lane forceps, large. 3. Lane forceps, large. 4. Lowman bone-holding clamp. 5. Lane elevator and retractor. 6. Hudson double-ended elevator. 7. Lane's bone-extension instrument. 8. Brun's bone curets, four sizes. 9. Caliper. 10. Sherman's screw-driver. 11. Sherman's vanadium steel bone plates, three sizes. 12. Sherman's tap screws, assorted. 13. Murphy's double ended bone skid. 14. Lane's heavy bone lever. 15. Sherman-Stille hand drill. 16. Horsley double-action bone-cutting forceps. 17. Stille double-action rongeur. 18. Periosteal elevators. 19. Periosteal elevators. (Sherman.)

traction enthusiast may persist in trying so long with traction and counter-traction methods that the operation finally done will be far more difficult

than if done early. It will be attended with added risk to the patient, with greater technical difficulties for the surgeon and with the loss of time consumed in unwise experimentation with traction and countertraction. It

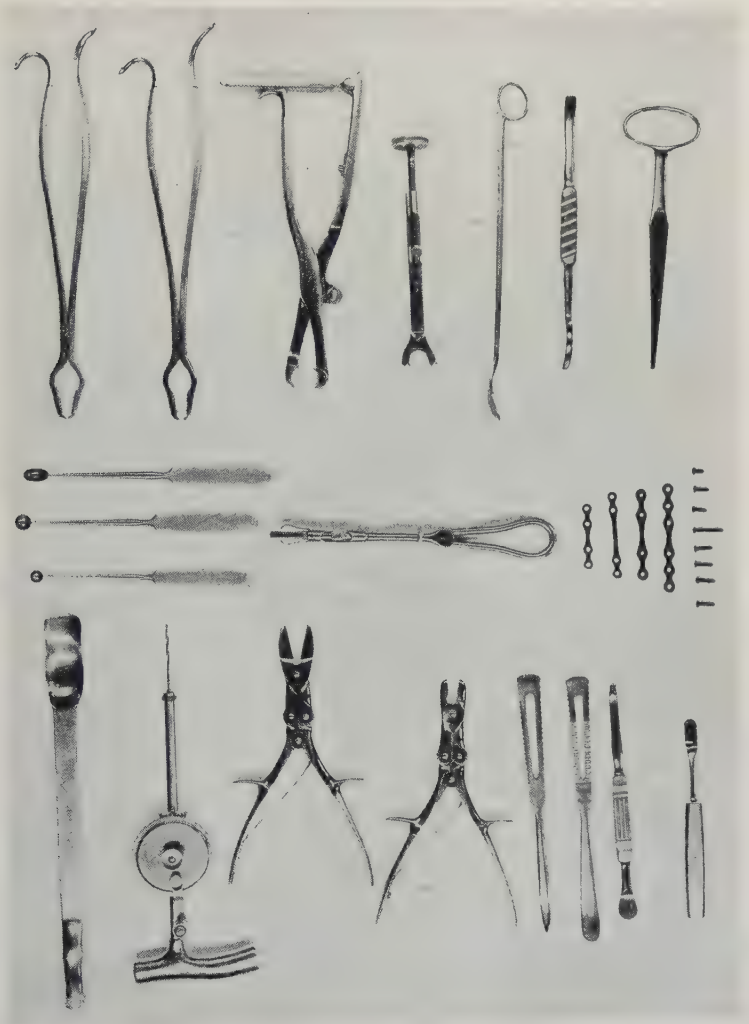


Fig. 1368.—Instruments necessary for operation on a fracture of the tibia (reading left to right): 1. Lane bone forceps. 2. Lane bone forceps. 3. Lambotte bone-holding forceps, medium. 4. Lowman bone-holding clamp. 5. Lane elevator and retractor. 6. Hudson double-ended elevator. 7. Lane's bone-extension instrument. 8. Brun's bone curets, three sizes. 9. Sherman's screw-driver. 10. Sherman's vanadium steel bone plates, four sizes. 11. Sherman's tap screws, assorted. 12. Murphy's double-ended bone skid, medium size. 13. Sherman-Stille hand drill. 14. Horsley double-action bone-cutting forceps. 15. Stille double-action rongeur. 16. Lane elevators. 17. Lane elevators. 18. Periosteal elevators. 19. Periosteal elevators. (Sherman.)

behooves the surgeon faced with a fracture to be treated to avoid handicapping either form of treatment and the patient by initiating treatment incorrectly. Delay in operation, delay in applying traction, are each serious.

Because disastrous and poor results have followed the operative treatment of open fractures and of certain closed fractures, this should not blind one to the results of such treatment under ideal conditions. As well might the traction method be decried because of the many failures following its unappropriate, inefficient, and delayed use.

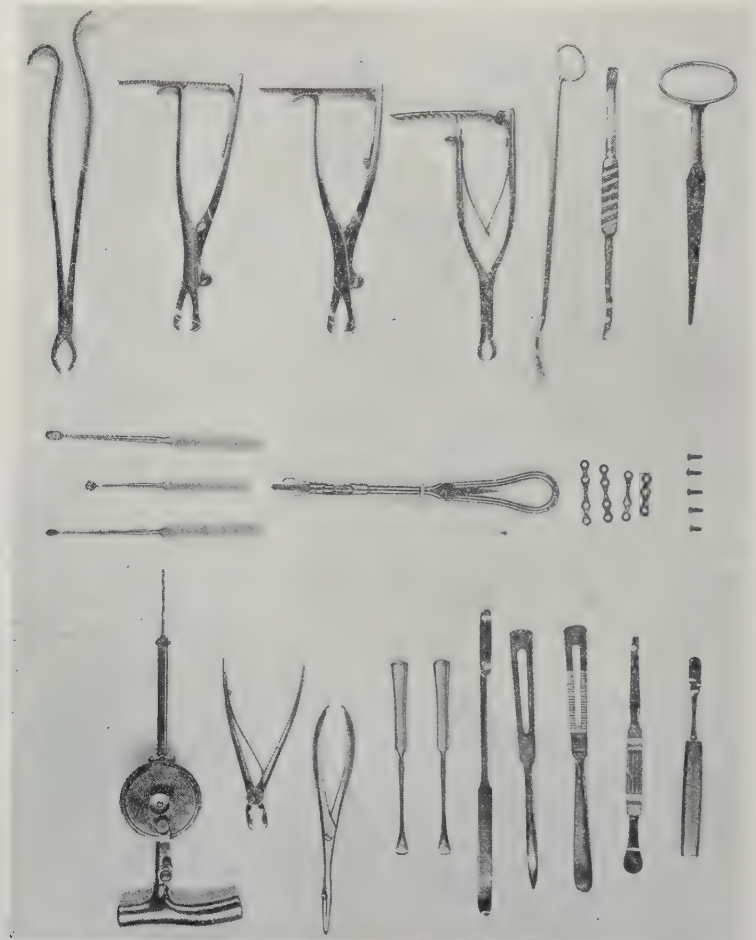


Fig. 1369.—Instruments for operation on a fracture of the arm (reading left to right): 1. Lane forceps, small size. 2. Lambotte bone-holding forceps, small size. 3. Lambotte bone-holding forceps, small size, 4. Berg bone-holding forceps. 5. Lane elevator and retractor. 6. Hudson double-ended elevator. 7. Lane's bone extension instrument. 8. Brun's bone curets, three sizes. 9. Sherman's screw-driver. 10. Sherman's vanadium steel bone plates, four sizes. 11. Sherman's tap screws, assorted. 12. Sherman-Stille hand drill. 13. Hartman's curved bone-gouging forceps (rongeur). 14. Sequestrum forceps. 15. Stille periosteal elevators. 16. Stille periosteal elevators. 17. Lane bone elevator. 18. Lane periosteal elevator. 19. Lane periosteal elevator. 20. Stille periosteal elevator. 21. Stille periosteal elevator. (Sherman.)

Because an amputation of the thigh was once done for fracture of the femur treated by skeletal traction after the traction apparatus had slipped into the knee-joint, causing an infection, this experience should not eliminate skeletal traction properly employed.

Because a compound fracture immediately fixed with non-absorbable material is followed by either amputation, infection, osteomyelitis, non-union, or death should not eliminate the use of non-absorbable materials properly used at such time in certain compound fractures.

The recognition of the value of certain procedures does not and should not depend upon the results of their *misuse*, but upon their correct employment. However one may group fractures, there will always be borderline and doubtful cases in which surgical good judgment must decide the pro-

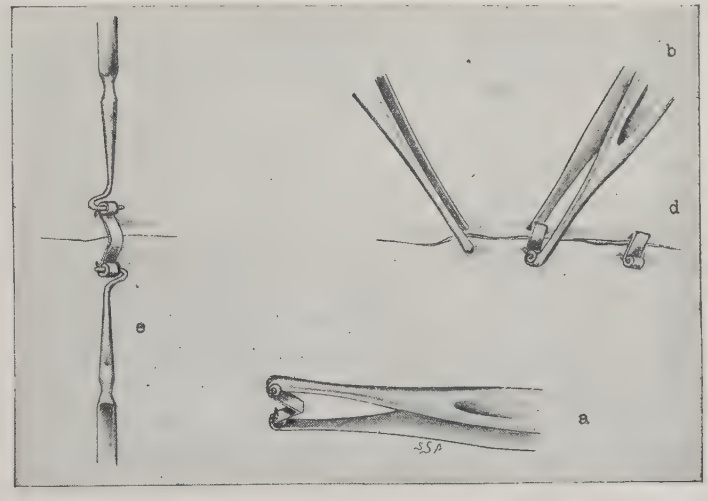


Fig. 1370.—Michel's skin-suturing instruments and technic: *a*, Michel clip, held in clip-forceps, ready to be applied; *b*, application of clips to skin-junction, which is being tautened and ridged by forceps just ahead; *d*, applied clip *in situ*; *e*, clip being removed, after healing, by Michel's clip-removing hooks. (From Bickham, Operative Surgery, vol. i.)

cedure to be employed. Satisfaction in the practice of an art rests upon the opportunity for the untrammeled exercise of sane judgment when all the facts are at hand in deciding a properly disputed question of treatment. This satisfaction comes to the surgeon who witnesses good results following a well-chosen treatment of a fracture of bone.

Because a femoral shaft fracture was treated after eight days lying in bed, supported by pillows, by skin traction of 10 pounds ineffectively, we do not discard the non-operative extension treatment of fracture of the shaft of the femur. Fortunately, the method does not rest on such experiences.

CHAPTER XXI

QUALIFICATIONS OF A SURGEON FOR THE OPERATIVE TREATMENT OF FRACTURES

THERE are at least eight requirements necessary for the surgeon operating upon a recent closed uncomplicated fracture. He should possess:

1. An adequate knowledge of the patient, physically, mentally, socially, industrially.

2. An exact knowledge of the local pathological conditions under consideration in the individual case.

3. Perfect instrumental, mechanical, and physical equipment including access to Roentgen-ray apparatus.

4. An accustomed proved operative technic, delicately balanced.

5. An understanding of the sensitive nature of bone tissue, its reaction to injury, and the conditions influencing the process of repair.

6. A practical experience in the successful treatment of certain fractures by modern non-operative methods.

7. A knowledge of the various operative procedures for the immobilization of fractures.

8. An open mind in choosing the method best adapted to the case in hand.

A surgeon having the above qualifications is capable of safely treating fractures by operation.

A surgeon not having these qualifications should not employ the operative method in treating fractures.

The only underlying fundamental reason justifying the ideal operative treatment of a simple closed uncomplicated fracture is the probability of effecting an earlier return of the part to a more nearly normal function than can be secured by any other treatment.

It is established that in skilled and safe hands the operative treatment of certain recent closed fractures is a safe procedure, with an almost negligible mortality risk, with a high percentage of restored normal function in a reasonable time.

It is also established that in skilled and safe hands the non-operative treatment of certain recent closed fractures is a safe and satisfactory method of treatment, securing a high percentage of restored normal function in a reasonable time.

It should be the aim of every surgeon of traumatism treating fractures to perfect himself in both of these methods.

The one method demands as much training and skill as the other.

A complete knowledge of the advantages and the technical details of each method is essential to the highest efficiency.

A general surgical training combined with a special technical mechanical training afford the most nearly ideal preparation for the treating of fractures that is possible.

Summary.—If you are a master of the general principles and technical details of both external and internal fixation and are informed as to the results of such methods of treatment and have a complete knowledge of the proper use of massage and active movement and can secure the patient's complete co-operation, your vision of the surgical treatment applicable to a given case of fracture of bone will be so broad, and your selection of the treatment will be so wise and your execution of the treatment chosen so ideal that the result both functionally and anatomically will be the best obtainable for that particular individual under the local conditions and environment found existing.

CHAPTER XXII

THE CONDUCT OF OPEN OPERATIONS UPON FRACTURES

SUMMARY OF CERTAIN OPERATIVE DETAILS APPLICABLE TO ALL OPERATIONS ON RECENT CLOSED FRACTURES

Anesthesia and the anesthetic—General—Skin—Instruments—Various paraphernalia—Incision—Protection of wound at skin edges—Knives for superficial and deep dissection—Retraction of periosteum with overlying muscle—Double gloved sterile finger—The delivery of the bone—A method of soft part retraction—The sponge count—The approximation of fractured fragments—The signs of the restoration of bone fragments to their approximal normal relations—The application of the steel plate—The choice and fixation of screws—The care of the soft parts—Temporary immobilization after application of internal fixation—Drainage of wound—Closure of wound of soft parts—Application of dressing—Application of external splint—Handling of the limb—Permanent position of the limb—Postoperative care.

ANESTHESIA AND THE ANESTHETIC

By Frank L. Richardson, M. D.

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The selection and the adaptation of the chosen anesthetic in a fracture case to the requirements of the situation is a matter of considerable importance. Believing that the selection of the anesthetic, the conduct of the anesthesia, and the general management of the case is of concern in all surgery, it seems timely to present the anesthetist's viewpoint in connection with fractures. The comfort and safety of the patient, the securing of sufficient muscular relaxation, the freedom of the surgeon from detailed responsibility, are considerations of great magnitude. The anesthesia should be entrusted to a trained and skilled anesthetist.

Simple Fractures.—Recent simple fractures of the long and short bones in young or middle-aged patients where no great relaxation is necessary and where only a short (few minutes) anesthesia is needed may well be done under a nitrous oxid-oxygen anesthesia. Very muscular patients and those considerably frightened usually require a preliminary narcotic. The narcotic chosen may be morphin sulphate, in combination with atropin or sulphate of scopolamin or magnesium sulphate, depending on the general anesthesic selected, and, too, upon the general condition of the patient at the time.

Narcotics are rarely if ever necessary in the very young or the very aged. If an operation on the aged is to be prolonged beyond a short time (one-half hour) a narcotic is quite desirable.

Complicated and Compound Fractures.—When the fracture is complicated or is compound or open, and a long period of muscular relaxation is needed by the surgeon, a preliminary narcotic is indicated. In such cases nitrous oxid oxygen, ethylene oxygen, alone or with ether, or one of these gases followed by ether may be used.

Manipulation of fractures of the long bones may, through the occurrence of fat embolism, be productive of shock. The anesthetist should, therefore, watch carefully for its occurrence during anesthesia in such cases. Frequent observations of the blood-pressure and pulse constitute the most delicate and reliable method of detecting the approach of shock.

Patients suffering from shock do very much better under nitrous oxid oxygen or ethylene oxygen anesthesia than under ether; and require very little if any narcotic. Spinal anesthesia and chloroform anesthesia are contraindicated in shock.

Certain systemic diseases complicated by fractures sometimes offer interesting problems to the anesthetist. *Diabetics* should not receive one of the fat-solvent anesthetics (chloroform, ether, ethyl chlorid) if avoidable because of the effect upon metabolism. When one of these anesthetics must be used, judicious treatment with insulin may prevent serious damage. The administration of a preliminary narcotic (morphin sulphate and scopolamin) followed by nitrous oxid oxygen anesthesia has very little effect upon the general metabolism.

Most valvular diseases of the heart if compensated need cause no great anxiety. Myocarditis, on the other hand, should not be looked upon lightly. There are few cardiac conditions which will contraindicate the use of an appropriate anesthetic for a short period.

Renal disease, especially if it is at all acute, makes it advisable to use one of the gases for anesthesia. If the fracture is of the lower extremity, spinal anesthesia may be used. In all renal disease ether and chloroform should be avoided. Chloroform and, to a slightly less extent ether, causes injurious cellular changes in the kidney and other organs.

Infants.—Newborn infants can generally be handled without the employment of a general anesthetic. If absolutely necessary, ether by the open method may be used safely.

Old People.—The aged tolerate most anesthetics well. Any very great variation in the blood-pressure should be avoided. Consequently, in the presence of arteriosclerosis and the associated degenerations care should be exercised in the choice of an anesthetic. Cyanosis should not be permitted to occur in the aged even for a very brief period.

In fracture of the nasal or malar bones the superior maxilla or the mandible without excessive hemorrhage the patient may be anesthetized by any of the usual methods for a short period. When bleeding into the mouth and pharynx is marked or when the anesthesia must be prolonged, an anesthesia continued with a pharyngeal or intratracheal tube, using the Cornell anesthesiometer or the Richardson vaporizor, is by far the safest method. The chief danger in these cases is the inhalation of blood or foreign material resulting in lung complications. The vapor method has the added advantage of removing the anesthetist from the field of operation and of maintaining an even anesthesia throughout any operative procedure.

Skull Fracture.—Fracture of the skull and head injuries with considerable intracranial pressure and unconsciousness may be operated without an

anesthetic, or, at most, with a very light anesthesia. At times a local anesthesia may be used. As many head injuries are in profound shock it is desirable to follow the condition of the patient by frequent blood-pressure readings and to use every means to keep the pressure within safe limits.

REGIONAL ANESTHESIA

Regional anesthesia is the result of a certain number of delicate surgical procedures by which it is possible to control pain temporarily by interrupting the sensory nerve conductivity of any region of the body (Labat). This anesthesia may be produced by field block or nerve block. Blocking the roots of the nerves within the spine in the subarachnoid space induces spinal anesthesia or intraspinal block (Labat) or an extensive regional anesthesia. Regional anesthesia, thus understood, may be employed, by a supraclavicular block, for operations upon the whole *upper extremity*. A circular band of skin infiltration above the immediate region concerned will assist in securing complete anesthesia.

Spinal anesthesia may be used under appropriate conditions for operations and bloodless reduction of fractures of the *lower extremity*. I desire here to direct attention to the use of regional anesthesia in the reduction of certain fractures and dislocations of the extremities.

Labat,[1] in his recently published book, has described the technical and clinical application of this regional anesthetic method. The injection at the site of a fracture of a local anesthetic is not altogether satisfactory. Regional anesthesia as advocated by Labat is a desirable method.

THE CONDUCT OF AN OPEN OPERATION

General Matters.—Postoperative lay criticism may be disarmed if the various phases of the contemplated operation are talked over with the patient, if intelligent, or with an immediate relative or responsible friend.

The usual pre-general anesthetic preparation is made (p. 748). The operation may be a somewhat prolonged one, especially if the time of application of a plaster-of-Paris retentive splint is included in the anesthetic period.

Preparation for a stated bone operation should be begun several days previous to the operation. It may be necessary in certain limb fractures to make extension and counterextension upon the fracture several days before operation (p. 751).

Skin Preparation.—Asepsis should be absolute. Abrasions, ulcerated areas on the limb, near to or remote from the field of operation, pimples and cellulitis should be treated and healed if possible previous to operation.

I believe that operation on a closed fracture should not be done if there is a suppurative focus known to exist in any part of the body. The liability of the operative field to infection directly or indirectly is considerable under these circumstances. If such liability can be avoided it certainly should be.

[1] Regional Anesthesia, Its Technic and Clinical Application, Gaston Labat, M. D., W. B. Saunders Co., 1924.

If adhesive plaster extension strips have been used on the limb, these should be removed previous to the operative preparation when possible.

A forty-eight hour (*i. e.*, the preparation is given twice with a twenty-four-hour interval) preoperative preparation of the skin is made as follows:

Washing the limb with soap and water.

Shaving the skin.

A second washing with soap and water.

Thorough drying.

Washing with 70 per cent. alcohol.

The application of a dry sterile dressing.

At the time of operation a washing with alcohol, covering the part with either picric acid (a 5 per cent. alcoholic solution) or with two coats of tincture of iodin full strength, U. S. P. That part of the limb not sterilized should be securely covered with legging or bagging of unbleached cotton.

The limb so prepared should be covered with sterile towels and sheets in such a way that traction may be exercised and manipulation of the limb may be conducted without breaking the asepsis. The towels are so arranged about the operative field that no part of the unprepared field can possibly be exposed.

The linen, towels and sheets, etc., are applied by the surgeon himself. Ordinarily, to the first assistant this important step may be delegated. Other assistants at the operation have not received sufficient training in this step of the operative technic to be entrusted with the important application of the sterile linen about the operative field.

Traction, Countertraction.—Preparation for traction and countertraction may conveniently be made on the Hawley table. This provision will preclude the necessity of using heavy distracting instruments on the bone directly through the soft wound. If the Hawley table post and foot support are not available, a folded sheet may be placed in the groin of the affected side, the two ends being carried up over the head of the table. The countertraction force may then be applied by a pull upon the two ends of this sheet. The traction force may be applied to the ankle through suitable towels looped about the ankle. I have used many times Martin's (Philadelphia) method of direct bony traction on the lower femoral fragment by a canvas strip looped at each end folded at the middle over the bone end—the two loops being attached to a traction screw on the table below the foot of the patient. The traction screw is attended by an assistant out of the operative field. Remarkably great traction force can be secured for old fractures of the femur by this method.

Position of the Limb.—The limb should rest supported on the table, or upon flat sand-bags or firm rubber-covered flat pillows.

Sterilization of Materials.—All dry goods, sheets, etc., gauze sponges, towels, etc., dressings, gauze, etc., are carefully sterilized. The gauze sponges used in the operative field are discarded immediately after the first soiling with blood. A careful sponge count is kept in every instance. All instru-

ments and rubber and cotton gloves are sterilized. All sutures, absorbable and non-absorbable, are sterilized. The surgeon's, assistants' and nurses' hands and arms are rendered sterile. Gowns and gloves are carefully adjusted. Special instruments for bone operations are to be accessible.

Handling of instruments, suture material, sponges, and fixation material is done so far as it is practicable by suitable forceps. When instruments are lifted it should be by the handle of the instrument. The touching of everything pertaining to the operation should be reduced to a minimum.

Splints.—Postoperative splints should be ready before operation. Plaster-of-Paris bandages should be prepared for the subsequent splinting. Thomas' lower and upper extremity splints should be on hand as needed.

Special Instruments.—Instruments used for fracture surgery should never be used for any other surgery. All septic bone work should be done by the aid of special instruments. None of the fracture instruments should ever be used in septic bone cases.

Spectators should be gowned, capped and masked, and kept at a suitable distance from the operative field.

General Remarks.—During the operation a properly protected finger may be introduced into the wound without fear of an infection arising from it.

All instruments are kept clean as they are used by washing in a 5 per cent. solution of hypochlorite, which is hemolytic, followed by washing in sterile water, and should be returned clean to the instrument table (Sherman). By this simple procedure one can readily maintain an operating instrument table free from blood-stains. A basin of sterile warm water is conveniently placed so that the operator may dip instruments into this solution before they enter the wound.

All tissues of the wound, including the bone, should be gently handled. In order to secure ideal healing with the minimum reaction, a surgeon should injure or traumatize the soft tissues as little as possible.

Slovenly work in this operative procedure cannot be tolerated.

The presence of sepsis in the skin and of discharging sinuses may delay the operation on the bone for a long time until healing has resulted. The use of sterile stockinette on the forearm over sterile skin, fixing the divided stockinette to either side of the incision by means of Michel clips, is simple and fairly effective in keeping the skin edges of the wound protected (Hey-Groves).

Whereas it is necessary to be specific in the description of an exact operative technic, it is to be understood that the rigid adherence to the standard here outlined is absolutely essential and imperative if successful operative fracture treatment is to be undertaken.

Variation from the precise methods laid down are allowable to meet certain individual surgical preferences or experiences which are compatible with safety. The operative standard technic cannot be too severe in every detail.

DESCRIPTION OF THE OPERATIVE TECHNIC APPLICABLE TO ALL FRACTURES

A recent simple closed fracture of the middle of the shaft of the femur is used as an illustrative case. It should go without saying that strict observance of a fully developed aseptic technic is to be carried out by every member of the operative team group. All previous preliminary preparations have been completed.

The Incision.—Lateral approach. The incision is made at the middle of the outer side of the thigh through the skin and superficial fascia. See p. 817 for anterolateral approach. The knife should enter and cut the skin absolutely at right angles to its surface so that square edges result. A long ample incision at least 5 to 7 inches is used. An adequate incision:

Permits of easy access to the fracture.

Diminishes the trauma from hard traction on soft parts (superficial wounds heal poorly when tissues are unduly pulled upon).

Eliminates guesswork in the deep wound approach.

Approximates to a visual attack on the bone.

Renders easy the manipulation of the fragments of the fracture, particularly if bending the limb is necessary.

A long wound will heal as readily as a short wound; no important structures are disturbed by the long incision. Primary union is expected. The chance of wound infection will actually be diminished by a long incision. All bleeding vessels are caught with the minimum of tissue. No blood should be allowed to stain the towels about the wound edges, so completely is the hemostasis cared for.

Protection of Skin Edges of the Wound.—Two properly folded dry sterile towels are affixed to the upper and lower edges of the skin wound. These towels should be held securely with no looping of the towel between the towel clips.

Towel Clips.—Short-handled towel clips should be used on the lower edge of the wound and long-handled clips on the upper edge of the wound (Sherman). Two clips should be used to each inch of the incision. A 6-inch incision should have, therefore, twelve clips on each side of the wound. (The Moynihan towel clip is appropriate, Fig. 1438. Long towel clips on the lower edge of the wound will dig into the table, injure the skin edges, and be knocked off, thus traumatizing the edge of the skin and proving ineffective.)

Shock will be lessened in the conduct of the operation by saving time in the conduct of the operation itself.

The various steps of the operation should be outlined beforehand in the mind of each assistant or helper at the operation. Each member of the operative team should be familiar with and know perfectly well his or her part and be ready when the time for his performance comes to act promptly, effectively, and without waiting to be told.

The loss of heat by the patient should be avoided:

By operating in a warm room.

By covering all parts of the patient's body other than the seat of operation by a warm blanket.

By covering exposed surfaces in the wound by gauze.

Fear on the part of the patient should be eliminated by making the preliminary preparation of the operation as little disagreeable as possible. The preliminary use of morphin and atropin subcutaneously about three-quarters of an hour before operation is often wise (see p. 748). The general anesthetic adapted to the individual and the necessity for complete muscular relaxation will be ordinarily secured by the employment of gas oxygen or ether (see p. 749).

Roughness in Handling Tissues.—A manipulation, if it requires to be carried out, should not be half done and hesitatingly done. It should be deliberate, firm, and final. Infinite gentleness, scrupulous care, light handling and purposeful quiet movements are all compatible with effective work and are necessary.

Avoid undue exposure of tissues to drying and cooling. Throughout the operation there must be no undue exposure of the soft parts of the wound.

Position of the Patient on the Table.—Patients under anesthesia are defenceless. They cannot feel and remedy strained and uncomfortable positions. The patient should be placed in that position most comfortable for the particular operation, and which will not add anything to his future suffering.

The Arrangement of the Sterile Coverings Around the Operative Field.—All parts of the patient's body and operating table must be covered with sterile sheets and towels. The limb to be operated upon should be so protected as a limb or unit that the whole limb can be manipulated if necessary without touching the skin of the patient or any uncovered part. If this provision is carefully made, many slips in the operative technic of fracture operations will be avoided.

At no stage in the operation should the simply gloved finger or hand of an assistant be allowed to come into contact with the patient's skin or the tissues of the wound. A no "skin touching" technic is maintained.

A fresh pair of forceps and scalpel should be used for all the deeper surgery. No scalpel that has touched the skin should be used in the rest of the wound for fear of an infection being started from the superficial tissues.

The deep fascia of the thigh is divided the full length of the skin incision. The fibers of the vastus externus appear. These fibers are separated and partly divided by a sharp scalpel. Several vessels will need ligation as the dissection proceeds. The junction between the vastus externus and the underlying crureus muscle will be found. The crureus muscle should be divided to the bone. (Consult diagram of cross-section of thigh at the middle, Fig. 1459.) No important nerves or vessels are encountered, but several vessels will require ligation.

Sponging the wound should be firm and localized, not a rubbing of the wound.

It is unwise to attempt to approach the femoral shaft through muscle planes alone. Keep constantly in mind that the plane of incision from this approach as one proceeds deeper and deeper is horizontal to the table.

Delivery of the Bone.—The crureus or even the vastus externus may have been torn by the fractured bones. If so, the approach to the bone is less conventional. On nearing the bone it is reached directly by dividing overlying muscle and periosteum together. The periosteum is thus retracted with muscle tissue attached. Blood-clot will be found in the space occupied by the fractured fragments. All bleeding vessels should be ligated with care.

The muscle bellies will be lax and soft, all tension and natural resiliency having given way to the fracture and the complete relaxation of active spasm because of the general anesthesia.

The double gloved sterile finger (a cotton glove over rubber) is a valuable and safe guide in the wound. Instrumentation, manipulation will be minim-

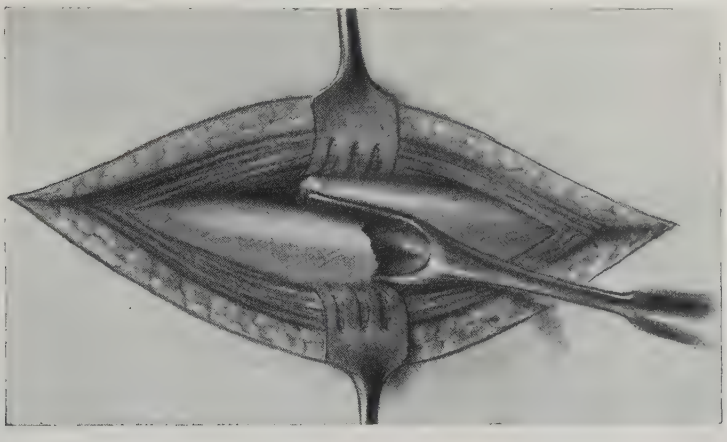


Fig. 1371.—Fracture of the shaft of the femur. Fragments free. Note application of lever to assist in reduction.

ized by tactile exploration. The difficulties of these bone operations are great enough with all possible assistance. There is no need to add to these difficulties by imposing upon the surgeon a quite needless restriction (Hey-Groves).

The bone ends of the fragments cannot ordinarily be delivered until the firm attachments to the linea aspera are severed (see Fig. 1371). The periosteum will have been stripped from the femoral shaft a varying distance by the injury. It is best, when necessary, to expose the bone remaining uncovered as has been indicated above, to incise the muscle, and to retract the muscle with the periosteum attached, not to separate muscle from periosteum. This is conducive to the more exact replacement of the periosteum when the wound is finally closed.

Deliver into the superficial wound that fragment that is the most easily and earliest reached. Suppose that it is the lower fragment, introduce a curved blunt hook (see Fig. 1358) carefully beneath the bone. Adduct the

leg and lower thigh away across the uninjured thigh so as to throw the end of the fragment into the wound. Traction on the hook and adduction will suffice ordinarily. Repeat these steps on the other fragment until it too is delivered into the wound. Adduction of the leg, as in the first instance, plus flexion of the upper thigh will with retraction of the soft parts accomplish this.

Keep the wound dry, free from blood and serum. Use large sponges after the vessels are ligated—*not small sponges.*

The *small sponges* after becoming wet with blood take on the color of the muscles and wound fluids and may very easily be lost beneath the muscle bellies in the depths of the wound. This precaution is exactly as necessary as is the care exercised in abdominal operations. Such a "lost sponge" may

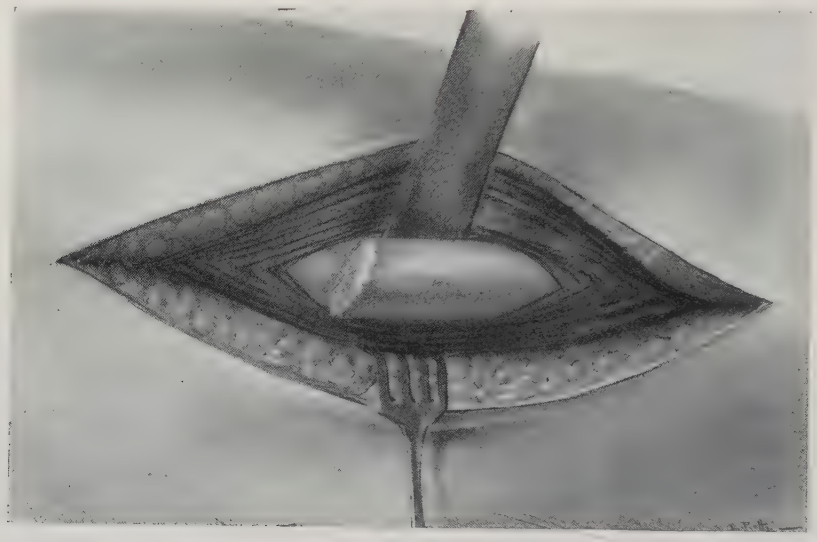


Fig. 1371A.—To illustrate, in operations on fracture of the shaft of the femur, the approach laterally (see p. 754 and cross-section of Fig. 1459). Note use of Harte retractor to assist in the delivery of bone fragment while at the same time serving as a retractor of the heavy muscle.

be left in the deep wound after reduction of the fragments and after suture of the soft parts.

Reduction or Approximation of the Fragments of Bone.—As the ends of the fragments lie in the wound freely there is seen to be an inch or more overriding. Three important things enter into this direct reduction:

1. Grasp each fragment with the large bone-holding long-handled forceps (see Fig. 1372, C).

2. Grasp in such a way as to be able to rotate the lower fragment in great measure and the upper fragment slightly about the long axis of each bone so that eventually the broken linea aspera edges come opposite each other accurately.

3. Bend the fragments at a sufficiently acute angle so as to engage the cortical part of each fragment with its opposite (Fig. 1372, C).

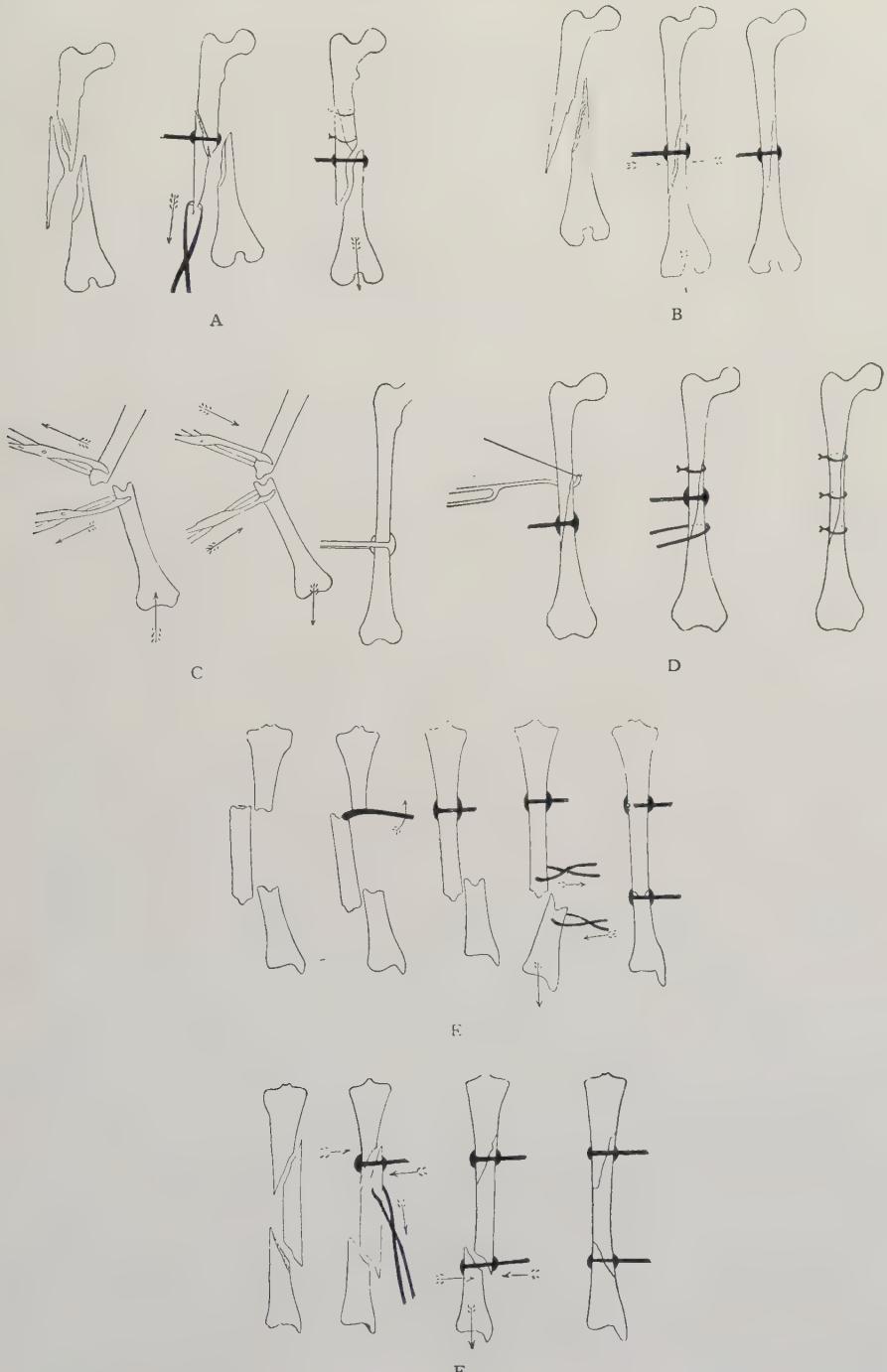


Fig. 1372.—A, B, C, D, E, F. These diagrams illustrate certain steps in the mechanics of the replacement of fragment ends, as well as offer helpful suggestions for immobilization after the displaced fragments have been replaced. (From Lambotte.)

4. Leverage, one bone end upon the other (Lane). Having thus rotated and engaged the ends of the fragments, it remains to force the ends into contact (see Fig. 1372, C). The restraining force that holds the ends from approximation is the retraction or elasticity of all the fasciæ of the thigh. All the intermuscular fasciæ, as well as the obvious fascia lata, furnish very extensive planes of fascia—all these fascial planes are retracted and shortened. It is against this tremendous fascial force that the reposition is directed.

Obviously, it is this force that will maintain the fragments after this approximation is secured. Consequently, it is very important that in the preliminary handling of the recent fracture too great traction is not used so that all this retractive force is eliminated, and is thus unavailable for holding the fragments together.

There will be cases in which some direct traction will be necessary upon the distal fragment before (in old fractures) or during the operation in order to overcome great overriding of the fragments. Certain oblique fragments will require holding by traction while being immobilized. At the time of the operation, provision having (in the routine preparation) been made for traction and countertraction without disturbing the asepsis, this distraction may be accomplished.

Firm Contact.—It is necessary in the bone-plating operation that the ends of the fragments be firmly in contact independently and apart from the use of a steel plate. When the plate is applied to such accurately adjusted bone ends, non-union cannot occur—union must follow.

It will be noted usually that there is an irregularity, consisting of a projection or bone process or point sticking down from the upper fragment for example. It will be the endeavor of the surgeon to engage this point of bone with the corresponding gap on the lower fragment. In other words, the surgeon will try to impact, to coapt, to approximate the fragments so that the normal anatomical relationships as in horizontal and right-angled planes are restored.

The patella of the injured side will have its accustomed relations to the anterior superficial surface of the thigh maintained. The linea aspera will have been restored. The jagged irregularities of the fracture line will be correctly engaged. Then the surgeon will be rewarded for his trouble by a restored appearance of normalcy of the contour of the thigh of the anesthetized individual.

Application of the Steel Plate.—While the fragments are held *in situ* and slight skin and muscle retraction is made, a flat steel spatula (Harte) (Figs. 1372 and 1397) is introduced to the under surface of the fracture as a protection, a guide, and retractor. Upon this thin flat spatula the clamp (Lowman-Scudder or equivalent, see Figs. 1359–1362) is placed and advanced under the fragments and is made to grasp each fragment. After the clamp is in place the large bone-holding clamps may be removed as well as the protecting Harte clamp. The steel plate (Sherman, Fig. 1395) held in the plate holder (Fig. 1355) is placed advantageously on the bone beneath the third anterior finger of the Lowman clamp.

The plate should rest on the impacted and correctly repositioned frag-

ments so as to permit of the placing of an even number of screws equally distant on each side of the fracture. Ordinarily, the plate will lie exactly parallel with the long axis of the femur. In most instances the periosteum will have been removed by the trauma of the accident or by the surgeon from these bone ends. The plate will, therefore, most always rest directly on the cortex of the femur.

I think it is best to have no periosteum beneath the plate. Little or no callus will form directly beneath the plate in any instance.

The Drilling of the Holes for the Screws.—Using the drill (Fig. 1341) through the holes of the steel plate as accurately as possible will help in the placing of the screws. The drilling should be continuous and at right angles to the plate against a slight lifting force applied through the bone clamp. When the drill point reaches the medulla it will be momentarily held up. A little additional force on the part of the surgeon will carry it into the medulla. If the short screws are to be used the drill may be withdrawn. If long screws through the cortex of the opposite side are to be used, the drilling should continue a sufficient depth into the opposite cortex. In removing the drill reverse the turning so as to withdraw the drill accurately; do not simply pull the drill out.

Introduction of the Screws.—The screws chosen should be perfectly finished. Occasionally the slot in the screw head which receives the screw-driver is so shallow that after the screw is almost in the screw-driver will slip out of the slot. An embarrassing situation may arise in consequence; therefore, inspect screws (Sherman).

The drilling of the holes and the placing of the screws are completed first in one fragment and then in the other fragment. Thus the plate is held in position on the bone and allows the drilling of the remaining holes without danger of the slipping of the plate.

Handle screws with the screw holder (Fig. 1353). Place the screw with the aid of the holder in the plate and the drilled hole in the bone, or use a screw holder and driver (Fig. 1394) in one instrument. Carry the screw almost completely in its full length. Place screws alternately on each side of the bone holder and the fracture if more convenient than placing all screws in each fragment separately. After all screws are placed go over each screw in turn and tighten securely. Introduce the flat spatula (Harte) beneath the clamp for protection of soft parts and ease in removing the clamp. Remove the bone and plate-holding clamp, sliding it out on the spatula. With this maneuver there is the least amount of trauma to the soft tissues. Remove the Harte spatula.

Inspection of the Site of the Operation on the Bone.—Introduce gently deep retractors so that the fragments as held by the steel plate may be readily seen. Move the lower limb slowly and gently in various directions so that it may be noted if there is any motion at all between the fragments. There should be none.

Care of Soft Parts and Wound.—Wipe gently all muscle bellies, smooth with scissors any jagged muscle-fibers irregularly divided in the approach

or damaged by the bone ends before operation. Dry the wound. Wipe the wound by means of swabs everywhere with alcohol 70 per cent. Dry the wound again. Ligate all possible bleeding vessels. Approximate with one or two interrupted absorbable sutures (No. 1 chromic catgut) the deep muscle-fibers (crureus) together with the retracted periosteum about the fracture site. These deep muscle-fibers may carry attached to their deepest parts bits of periosteum. It is important to approximate these periosteal strips to the bone. Bring together the fascia lata with interrupted sutures (No. 1 chromic catgut). A *continuous* fascial suture should never be used.

Provide No Drainage.—Suturing the fascia edges interruptedly will permit seepage of blood and serum to the surface if there is any bleeding. A drain, however short a time left in place, is more likely to introduce sepsis than to provide for any necessary escape of fluid. Drainage is contraindicated in primary clean operative bone wounds. I have never regretted omitting a drain under these conditions.

The superficial fascia and subcutaneous fat are sutured interruptedly by zero plain catgut. These superficial tissue sutures help to approximate the skin; fewer skin sutures are needed.

The skin incision is closed by interrupted sutures of linen. I prefer this to silkworm-gut or catgut or metal clips.

Up to this point in the operation the thigh has lain on the table (Hawley or equivalent) supported by pillows or sand-bags in a position of rest.

Application of Dressing.—In order that there may be provided at once support to the fracture site, so that all strain may not be assumed by the fracture or plate, with a likelihood of an undue strain on the screws, resulting in the loosening of the screws or even a fracture of the steel plate, I like to use a piece of sterile splint wood about 18 inches long and 2 inches wide.

This narrow sterile splint is protected by two folded sterile large gauze compresses or sponges; thus padded, it is placed behind the thigh next the skin and is incorporated in the dressing.

This posterior splint may be made to assist materially in preserving the normal anterior bow of the femoral shaft by carefully placed sterile gauze padding (Fig. 810). This will be true whether the splint used is a plaster spica or a Thomas splint. The wound dressing of dry gauze is applied so as to encircle the thigh. It is held by a sterile gauze bandage evenly applied. It is important that this dressing should cover the wound and extend at least 4 or 5 inches above and below it. It should also encircle the thigh. It will thus be evident that in lifting the limb for the subsequent application of the Thomas splint or plaster-of-Paris spica due support is afforded by the small posterior splint.

The handling of the limb should be delegated to a trained and trusted assistant. I believe much harm is done by a thoughtless handling of the operated limb from the time of the closure of the wound until the finish of the retentive splinting.

The trusted assistant will handle the limb permitting motion at the hip and knee, but allowing no strain at the fracture or the plate site. This

handling is an art to be cultivated. It is an important part of the operative procedure.

The splint will be either a Thomas splint or a plaster-of-Paris spica splint. Personally, I use the latter. I believe that there are distinct advantages in the use of the Thomas splint with the Pearson knee attachment as employed by Sherman. A splint of some sort is needed for the immediate protection to restlessness following the general anesthetic.

The ideal position to be maintained for the treatment of the involved limb will be:

Abduction of the shoulder—extension of the elbow—supination of the forearm—dorsiflexion of the wrist—flexion of the hip and knee—dorsiflexion of the foot at the ankle. These positions are the positions of greatest muscle equilibrium.

If the Thomas splint is used the Pearson leg attachment will allow of early flexion and extension of the knee. It is of great advantage (Fig. 1041).

In applying the plaster spica to the patient following operation with the help afforded by the Hawley table, there is little or no moving of the patient. The plaster splint is quickly put on.

The Position of the Lower Extremity.—The thigh should be slightly flexed on the abdomen; the knee slightly flexed on the thigh; the (ankle) foot at a right angle with the leg.

I have at times after this operation immobilized the lower extremity partially by a snugly fitting plaster-of-Paris splint extending from the toes to the groin of the affected side. This can be done when the fracture of the femur is below the middle of the bone.

A splint of this extent suspended so as to clear the bed will permit of motion at the hip-joint and may be a bit more comfortable for the patient and as efficient as the complete spica.

Leland's Knee-joint Flexion Splint.—In order that active and passive flexion and extension of the knee-joint may be secured during the necessary immobilization of the fracture of the femur Leland has devised and used an iron caliper knee-jointed splint (Fig. 1373). This splint is incorporated in the plaster-of-Paris splint (Fig. 1374). By its use earlier motion is possible in the convalescent period following thigh fracture treatment with or without operation. Of course this splint is less applicable the nearer the fracture is to the knee-joint.

Postoperative Care.—The circulation of the extremity if plaster-of-Paris splints are used must be frequently inspected during the first forty-eight hours. Plaster-of-Paris encircling splints must be split if any sign of compression appears. It is wise to always split the plaster-of-Paris splint immediately after its application.

If there are appearances of oozing of blood, these stained surfaces should be covered by sterile dressings. The external splinting, whether a plaster-of-Paris or steel Thomas splint, should adequately fix the fracture, thus removing all undue strain on the internal fixative material.

Fig. 1373.—Leland's metal caliper knee-joint to be incorporated in a plaster-of-Paris splint (see Fig. 1374)

Fig. 1374.—Leland's knee caliper incorporated in a plaster-of-Paris splint to pelvis and leg. Note that movement at the knee is possible during convalescence from fracture of femoral shaft.

The patient should be made comfortable with morphia subcutaneously administered during the first forty-eight hours. The plaster-of-Paris splint should be reapplied after three or four weeks.

The plaster-of-Paris splint should be employed as long as it would be if no internal splint (steel plate) had been used, and, in addition, one or two weeks longer.

Rapid restoration of function by guarded and guided active movements are to be encouraged and employed as early as possible, ordinarily after from four to seven days following operation.

The protection of the limb while the callus is soft and pliable is very important. Rest is essential to the initial stages of repair.

(For special regions and special bones see p. 882.)

CHAPTER XXIII

METHODS OF DIRECT FIXATION OF FRAGMENTS BY OPERATION

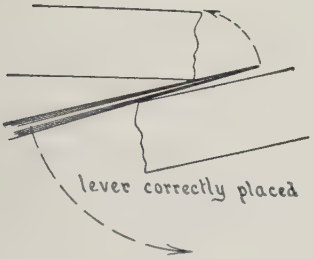
Conditions determining choice of procedure—Methods of direct fixation—Impaction of ends—Leverage—Artificial impaction—Use of wire—The Parham band—Gatellier's instrument—Cotton applicator—Operation of wiring—The process of repair—Removal of wire and bands—Intramedullary pegs—Use of bolts—Use of steel plates—Sherman tap screw—Disadvantages said to follow use of screw—Zierold's experimental work—Use of ivory—Advantages of ivory—Principles in use of ivory—Ivory screws—Sterilization of ivory.

HAVING decided to operate, the final choice of the special procedure will depend somewhat on several different conditions: Irregularities of the ends of fragments; variations in the density of the bone or the holding power of the bone tissue; the necessity of stripping muscle attachments from the bone to secure access to the bone; the liability to considerable hemorrhage attending such an extended dissection; the probability of severe muscle pull displacing fragments and hence stressing the retentive fixation; the age of the fracture; the age of the patient; the amount of callus; the general condition of the patient; the presence of other wounds and injuries; the damage to the soft parts; the line of fracture, its obliquity or comminution.

Methods of Securing Direct Fixation.—(*a*) *Impaction of the Fractured Ends Through an Incision.*—An irregular slightly oblique fracture in certain situations may be locked through an incision without the use of internal fixation apparatus. This operative procedure affords all the advantages of palpation and a direct vision of the fragments.

Because a fracture seems to require an open operation does not necessitate the employment of any special form of fixation material. This is true especially of fracture of parallel bones, as of the tibia or of the radius with an intact fibula or ulna. An incision, removal of obstructing tissue, and leverage will result sometimes in reduction and close approximation.

Leverage as Employed in the Operative Treatment of Fractures: Many fractures with displacement can be replaced by an incision over the site of the fracture and leverage upon the fragments. Often simple locking of the fragments will maintain reduction of the fracture. I have had constructed and have used for some years a set of levers for this purpose. One side of each end is rough, one side is smooth, each side is grooved (Fig. 1357). The long lever thus devised makes the procedure of leverage comparatively easy to carry out. The use of instruments ill adapted is harmful and often ineffective. The conception that every operation upon a fracture necessitates the use of some metallic fixation material is unfounded. Simple incision and leverage is a procedure of value and importance and should be used more frequently than it is.



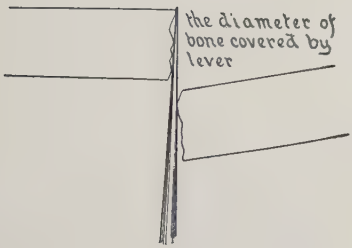


Fig. 1375.

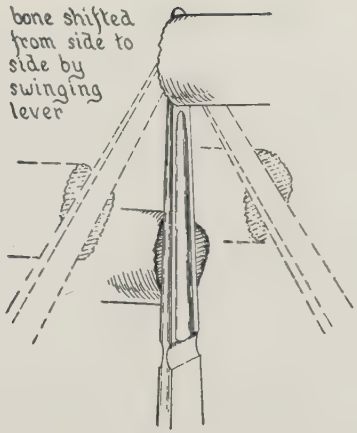
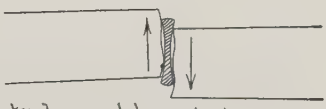
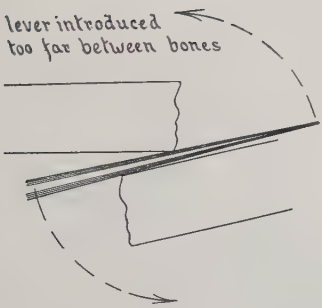
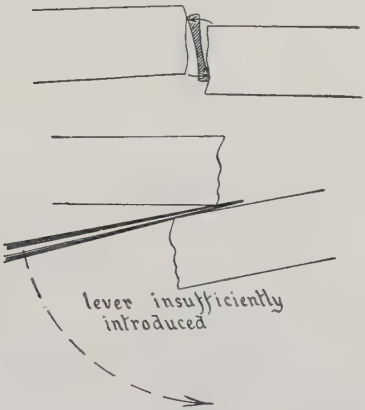


Fig. 1376.



checked by twisting lever





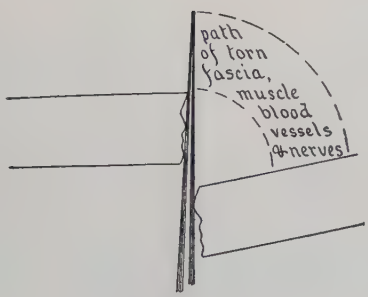


Fig. 1377.

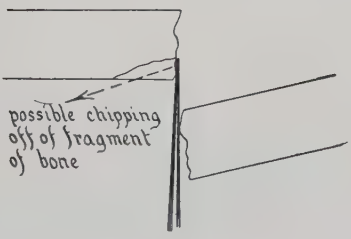


Fig. 1378.

An absorbable suture will maintain satisfactory apposition in a certain few cases until suitable external splinting secures the snug permanent coaptation of fragments. Fractures of the surgical neck of the humerus lend themselves to this method of treatment.

(*b*) The *artificial impaction of reduced fragments* may be supplemented in certain instances by carefully placed absorbable, kangaroo, chromic catgut, or autofascial suture (Gallie). At times a wire suture may more securely and satisfactorily maintain reduction.

(*c*) *The Use of Wire and Bands of Steel.*—In certain circumstances the employment of wire and bands of steel for fixation of a fracture is advantageous.

If wire is used, it must be soft, strong, and not brittle to allow of twisting. The standard gauge Nos. 18, 16, and 14, soft annealed, not hardened, iron wire, is useful. I have found aluminium bronze wire useful at times. The Vienna braided bronze wire is satisfactory.

Instruments Needed in the Use of Wire.—There will be required a small hook with which to catch the wire loop after it has encircled the fracture; a twister to tighten the wire and then to twist it securely; wire scissors

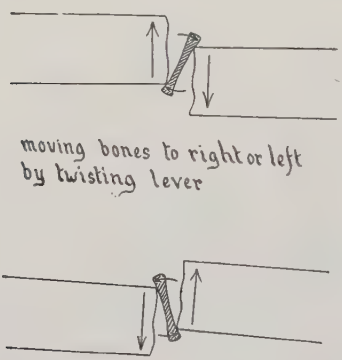


Fig. 1379.

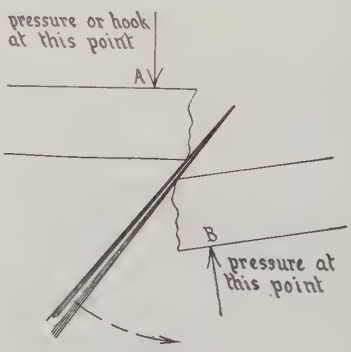


Fig. 1380.

or cutters; a hammer and blunt tamp with which to bend and approximate the wire to the bone after it has been twisted.

Wire has been used frequently by Archibald Young, Glasgow, successfully. A recorded case of fracture of the lower jaw shows one method of use of wire.

Wire may be used as a simple suture to steady two fragments brought into contact, very much as one at times uses a kangaroo and a chromic catgut suture.

Wire may be used as a mattress-suture introduced through holes drilled in the fracture fragments while held perfectly reduced by a clamp. Wire thus introduced should be tightened by twisting three times, cut, and the

ends buried beneath the soft parts. Wire may be appropriately employed in fracture of the patella and in fracture of the olecranon.

Wire may be used to coapt or appose small attached fragments to the main shaft. Wire thus maintains lateral pressure.

The most ideal place in which to use wire is in the long oblique fracture of the shaft of a bone, particularly in long oblique fractures of the shaft of the femur. In a long oblique fracture one encircling wire ever so accurately applied will not prove constantly effective. It is best to apply two encircling wires. These should be placed a little distance from the ends of the fragments to secure the greatest mechanical advantage (see Fig. 1386).

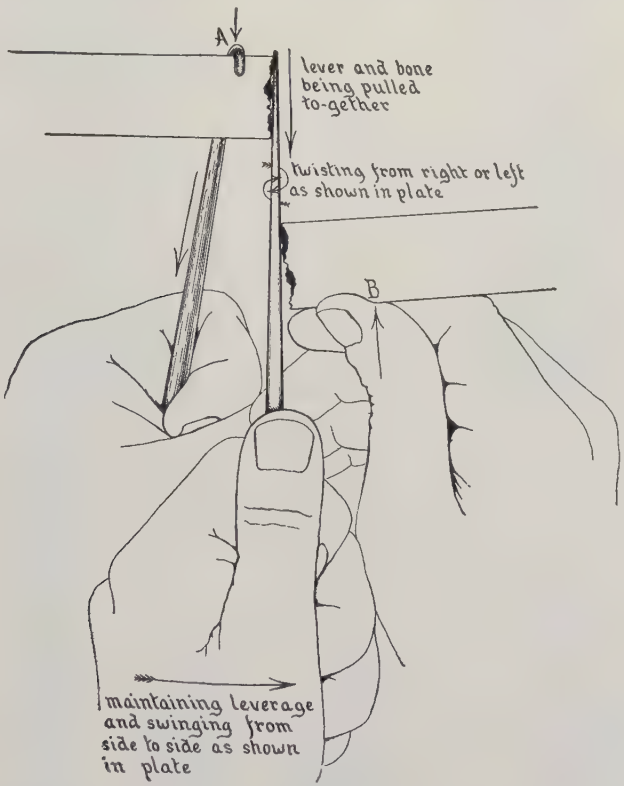

A
lever and bone being pulled to-gether
twisting from right or left as shown in plate
B
maintaining leverage and swinging from side to side as shown in plate

Fig. 1381.

The Parham Band or, as it is Known, the Parham-Martin Band.—The instruments needed for the application of the band: A Parham or Gatellier (Paris) tractor. If the Parham tractor is used, a blunt aneurysm needle threaded may be used to pass the thread carrying the band about the bone. The aneurysm needle and the band are liable to become entangled in torn soft parts. The thread holding the band to the needle may break. There may be considerable difficulty and delay in placing the band by this simple method (Fig. 1382). The Hagie[1] band and introducer are useful.

[1] Jour. Amer. Med. Assoc., March 20, 1926.

A hollow aneurysm or director-like instrument has been used. The band is threaded through the director and follows the director around the bone.

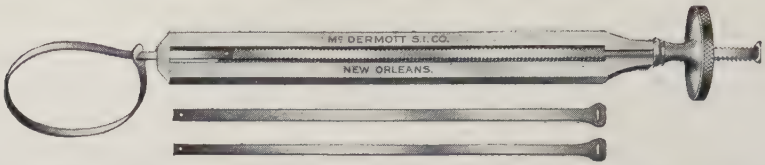


Fig. 1382.—Parham-Martin band applicator. Band is introduced about fracture fragments, looped, attached to center rod of instrument. By turning wheel, rod is moved away from fracture, carrying loose end and tightening loop about fracture.

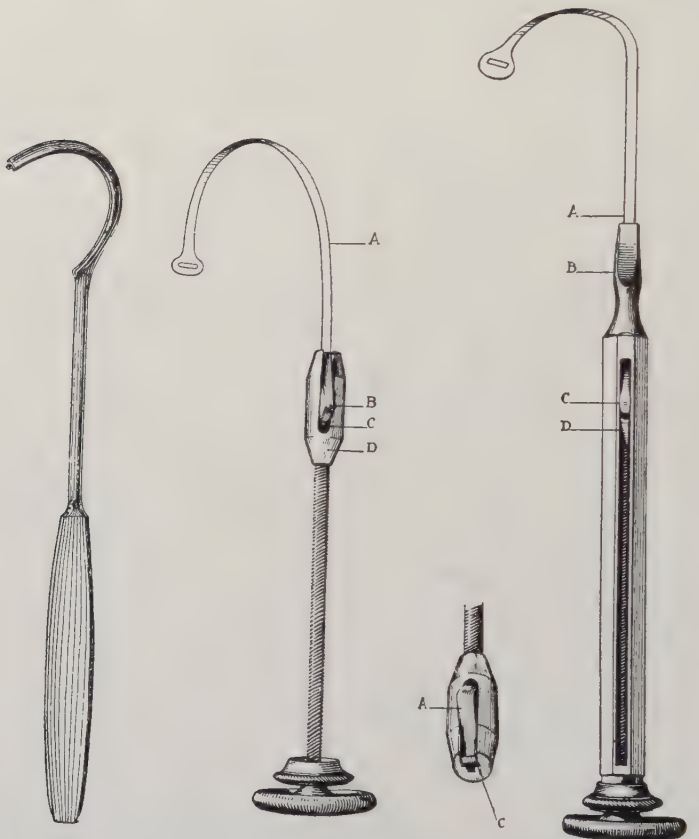


Fig. 1383.—Banding instrument of Gatellier (British Journal of Surgery, vol. 9, p. 259).

Gatellier's instrument is useful and I give Stanley's description of it (Fig. 1383):

The threaded stem of the tractor ends in a shell "nose cap" which fits into the hollow extremity of a cylinder containing this stem. The latter at its end has a slit the exact size of the band. The band introduced through the slit meets an exactly similar slit in the "nose cap," traversing the latter it meets a cam which lifts the moment the slot of the

band engages the former, a spring snapping back the cam into the slot. The band is tightened about the bone by the wheel on the stem. The band is disengaged from the cam by slight pressure on a button.

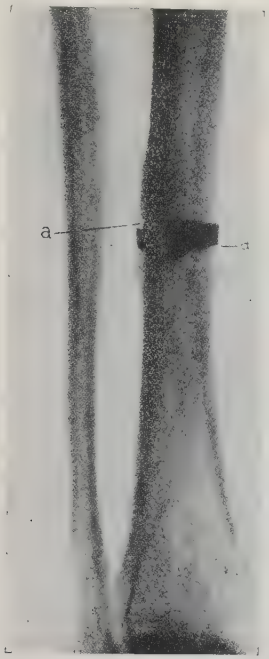


Fig. 1384.—Fracture of tibia and fibula. Band to tibia. Appearance eight months after the operation. A perfect functional and anatomical result. Note *a*, a slight constriction by band. Age of patient forty. (E. G. Stanley and Jean Gatellier, British Journal of Surgery, vol. 9, p. 258.)

Fig. 1385.—Same fracture band as in Fig. 1384 seven months after the operation. Note at *a* a rather large clear space in contact with the band. (E. G. Stanley and Jean Gatellier, British Journal of Surgery, vol. 9, p. 258.)

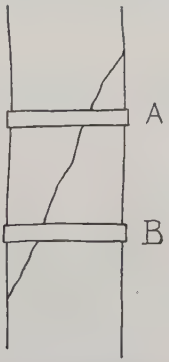


Fig. 1386.—Illustrating diagrammatically the correct placing at A and B the bands in banding a fracture. Note line of fracture and that one band would not hold as securely as the two well-placed bands.

The instrument takes apart for sterilization and is easily reassembled and has proved satisfactory. The band used is of steel with sufficient carbon to give it just the right degree of rigidity. The width of the band varies from 3 to 5 mm.

Cotton-Dunn Wire Applicator (Fig. 1387).—The strand of wire used has a loop brazed at one end. The wire is passed about the bone and the ends passed crosswise through the oval smooth edged hole in the tip, then up on either side of the cross-bar.

(*a*) The looped end goes over the hook.

(*b*) The free end is clamped by a cam lock under the ring nut.

(*c*) The handles are closed until the wire is fairly snug about the bone. The tension obtained is held by the ratchet.

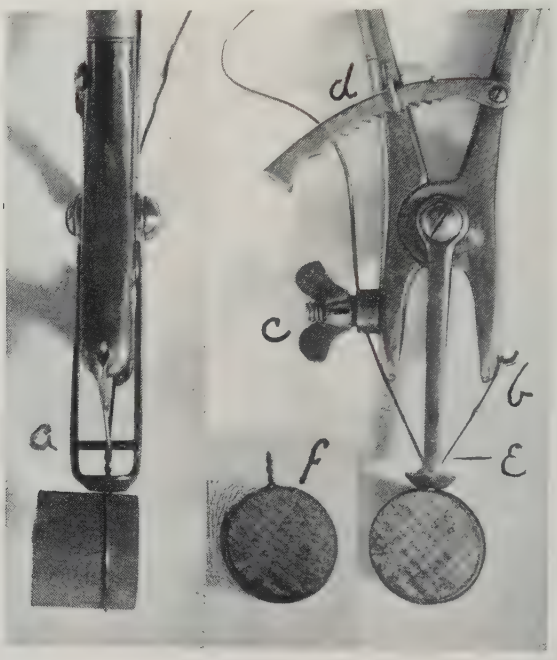


Fig. 1387.—Using the Cotton-Dunn applicator. The strand of wire used has a loop (brazed) at one end. The wire is passed about the bone and the ends passed crosswise through the oval, smooth edged hole in the tip, then up on either side the cross-bar (*a*). The looped end then goes over the hook (*b*), the free end is clamped by a camlock under the wing-nut (*c*). The handles are then closed until the wire is fairly snug. The tension is held by the ratchet (*d*). Then the whole instrument is twisted: the smooth hole in the tip makes the spiral close and the cross-bar (*a*) crowds the turns down close. The wires are cut at the level of *e*. The loop is flattened over on to the bone. How close the wire band is drawn may be seen from the insert at *f*. (Cotton-Dunn, Surg., Gynec., and Obst.)

(*d*) The whole instrument holding the wire is turned so as to twist the wire. The smooth hole in the tip makes the spiral in the wire close to the cross-bar (*a*) and crowds the turns down a bit. The wires are cut at this level.

(*e*) The loop is flattened over on to the bone. How close the wire band is drawn about the bone may be seen at *f*.

Operation of Wiring or Banding.—(*a*) The fractured ends of the shaft are exposed.

(*b*) The fragments are accurately reduced.

(*c*) They are carefully held reduced by a bone-holding clamp (Lowman)

(*d*) The wire or band is made to encircle the bone at the appropriate levels. The encircling material is (*e*) tightened, (*f*) fastened, (*g*) severed, and (*h*) the ends are folded into place.

The deep and superficial soft parts are carefully closed over the bone and the internal splint by interrupted absorbable sutures. The skin wound is closed by interrupted Michel clips or fine linen or fine silkworm-gut.

The application of the band to certain long oblique fractures of the shafts of long bones is ideal in its results. Certain comminuted fractures may be assembled and held firmly reduced, coapted by the band. The band is flat. The underlying bone is less likely to be damaged than by a tightly constricting wire.

The Process of Repair in the Presence of Encircling Bands.—By the fifteenth day (Stanley and Gatellier[1]) there is seen by Roentgen ray a shadow surrounding the operative bone field. By the twenty-fifth day the same observers record that the shadow extends along the shaft of the bone. Callus surrounds and completely covers the band. If the band is properly applied there is no delayed union following its use. There is no necrosis of bone following the use of the band. The callus formation is delayed at the point of contact of the band and of the bone. It has been noted that the callus is better developed on the side of the bone distant from or opposite to the approach to the bone, that is, opposite the incision in the soft parts. Many times the band is completely buried in bone and remains indefinitely innocuous.

It is desirable that *mobilization of joints* contiguous to the fracture should begin as early as is compatible with safety, that is, as early as such mobilization will not interfere with repair at the seat of fracture.

After using the band Stanley and Gatellier (Paris) began mobilization very guardedly in fractures of the forearm on about the second day after operation; in fractures of the leg about the fifteenth day; in fractures of the upper arm about the tenth to the twentieth day; in fractures of the femur about the fiftieth day.

The external splint suited to these cases may be one of plaster of Paris. This splint may be bivalved. The mobilization of the limb will be comparatively easily accomplished by removing the anterior part of the bivalved plaster-of-Paris splint.

The limb I think may be best supported in a carefully applied Thomas splint.

Removal of Wire and Bands.—I believe that it is wise to remove the wire or bands from the bone after they have served the purpose for which they were introduced, that is, the maintenance of reduction until sufficient callus has formed to hold the fragments securely. Having done their duty they should be removed to preclude all the disagreeable events which may follow in retention of foreign bodies, necrosis, refracture, sinuses, and osteomyelitis. It makes no difference that a certain operator has used the band or wire for several years and advocates leaving them *in situ* as harmless. There are certain cases in my own experience and in the experience of others in which

[1] British Journal of Surgery, vol. ix, 1921–1922.

the band after having been employed ideally has given trouble and removal was compulsory, with otherwise satisfactory results. This experience, of course, may be duplicated. The fact that very occasionally some difficulty follows the correct employment of any method should not discourage the use of an efficient surgical procedure.

Intramedullary Pegs or Grafts.[1]—Pegs of ivory or bone driven into the medullary cavity of the shafts of long bones afford a simple and at times a very efficient method of fixing fractures and stimulating bony union. That the intramedullary graft hinders and prevents union is disproved by clinical experience. If the peg or graft is loosely placed, obviously a fracture of the peg or graft may occur, or union may be delayed by the very great movement at the seat of contact. Slight motion at the seat of contact probably does not prevent, but rather stimulates, osteogenesis. If a peg or graft is placed in firm contact over a long distance in the bone medulla, no harmful effect may follow. The intramedullary peg is applicable to a clean aseptic closed transverse non-comminuted fracture. The peg or graft may be made of beef bone or be an autotransplant from the patient's tibia. It is convenient to have at hand various sizes of beef bone pegs in case it is undesirable to secure an autogenous graft. These pegs or grafts may be for the radius or ulna about $\frac{3}{16}$ inch in diameter; for the humerus $\frac{3}{8}$ inch; for the femur $\frac{1}{2}$ inch in diameter.

The medulla should be carefully reamed out by twist drills of the corresponding size, so that when the pegs or grafts are admitted into place they will fit very snugly. In recent fractures a beef bone peg will serve every purpose. Only in ununited or old fractures will an autogenous peg-graft be desirable. An irregular graft or peg of bone will often fit more snugly than a cleanly made peg or screw of bone, the very irregularity helping to secure firmness of contact.

Mr. Hey-Groves has recommended and used very mechanically ingenious methods of inserting pegs and grafts in the medulla.

The Thrust or Nail Method.—As in pegging the proximal ulna fragment to the shaft of the ulna in olecranon fracture; as in the long nail of bone into the neck of the femur through the base of the trochanter.

The Thrust and Split Method.—As in the long bone with no loss of substance; the graft is driven into one fragment, it being impossible to place it in the other fragment, that other fragment may be split for a few inches longer than the graft to be inserted. By saw and osteotome the split fragment is held wide open and the end of the graft is slipped in between the splits. These are allowed to come together and hold the graft. The split fragment may be encircled by wire temporarily to hold the split portion tightly against the graft.

The Trap-door Method.—Like the split method, one end of the graft is thrust into one fragment and a trap-door down into the medulla of the other fragment lets the graft into place, and the trap-door is closed over and held securely in place by suture or temporary encircling wire or fascial band.

The Side Grafting.—One end of the graft is put into the medulla of one fragment and the side of the other fragment is prepared to receive as a graft the other end of

[1] Modern Methods of Treating Fractures, E. W. Hey-Groves, The MacMillan Company, 1921.

the graft. This lateral graft is held to the fragment by peg or bone or ivory or by temporary encircling wire.

The intramedullary bone-graft may be used in fractures that are transverse or nearly so, in fractures that are clean, and in fractures without great comminution of fragments (Hey-Groves). The intramedullary graft may be advantageously used in certain fractures of both bones of the forearm, in fractures of the radius alone, and in certain fractures of the tibia.

Disadvantages of the Intramedullary Peg.—The necessary reaming out of the medulla destroys a certain amount of bone tissue. This is thought by some to hinder the reparative process so far as the medulla is a factor in this process.

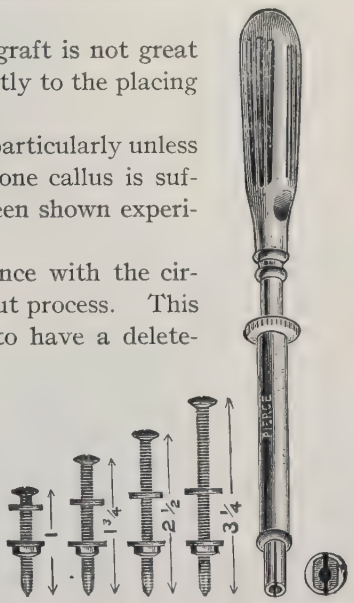
The fixative power of the intramedullary graft is not great unless the external splinting applied subsequently to the placing of the intramedullary graft is very effective.

There is a liability to a fracture of the peg particularly unless the external splinting is continued until the bone callus is sufficient to take care of all strain. This has been shown experimentally by Davis.

There is thought to be a definite interference with the circulation of medullary tissue in the reaming out process. This interference with the circulation is thought to have a deleterious effect upon the process of repair.

Unless beef bone or ivory pegs are employed there will be two operations needed upon the same individual at the same time in taking the graft from the patient's tibia.

Fragments are said at times not to be held in good alignment by this method. In answer to this it may be stated that if great care is exercised in the postoperative supervision of such a fracture the alignment may be maintained.



1387A.—Bolts made from Sherman screws, nuts and washers.

The Use of Bolts, Nails, Screws, and Pins.—*Bolts* can be occasionally used to advantage if the bone involved is approachable from both sides. An oblique fracture through a femoral condyle with separation Hey-Groves selects as the type of fracture for bolts par excellence. The bolt cannot be displaced and is difficult to remove if this is ever necessary. Bolts of the thickness of $\frac{1}{8}$, $\frac{5}{32}$, and $\frac{3}{16}$ inch are useful made of soft steel, easily cut by wire cutters. The small size is used for holding a step-cut of the humerus and the larger size is used for the shaft of the femur. In certain situations the smallest bolts and nuts may be used to hold the steel bone-plate more securely even than screws will hold it (Fig. 1387A).

Ordinary carpenter's *nails* and nails of ivory and beef bone regularly fashioned or slightly irregular in contour have a place in the surgeon's armamentarium. Lambotte employs fine wire nails for holding detached and dis-

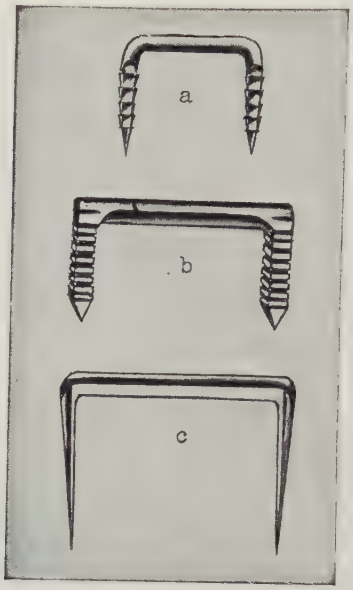


Fig. 1388.—Metallic bone staples for fixing fractures: *a*, Roux-Lane's bent wire; *b*, Jakael's corrugated; *c*, Schedd's plain steel staple. (From Bickham, Operative Surgery, vol. ii.)

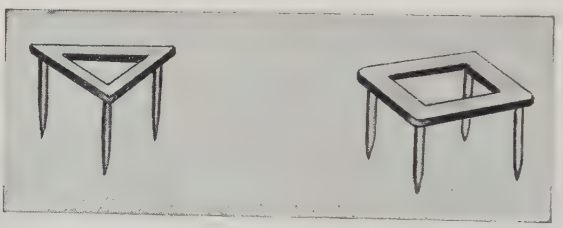


Fig. 1389.—Lambotte's gold-plated bone spikes, three and four pronged. (From Bickham, Operative Surgery, vol. ii.)

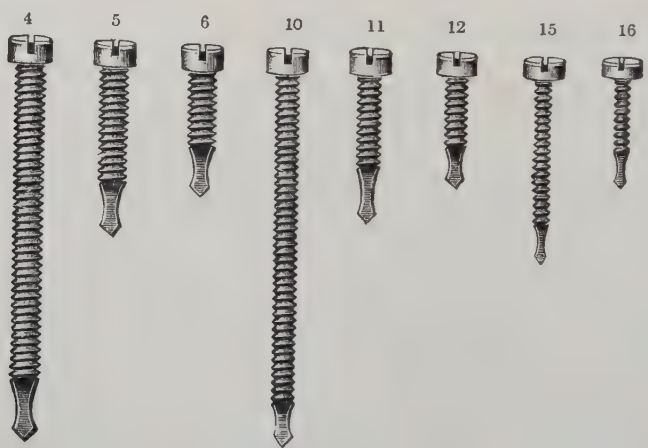


Fig. 1390.—Lambotte screws used in holding bone fragments reduced.

placed fragments, epicondyles and condyles, and displaced tuberosities. Hey-Groves ingeniously suggests that bone knitting needles will be useful, for they

Fig. 1391.—Fracture at ankle-joint (Henderson).

Fig. 1392.—Same case as in Fig. 1391. Appearance nine months after a beef bone screw operation. Note reduction of deformity and note especially the bone screw in the lower end of the tibia lying transversely to the long axis of the tibia in process of absorption (Henderson).

can be cut with wire cutters the required length and fashioned at either end with a suitable file.

Staples are at times extremely helpful in temporarily steadying bone fragments (Fig. 1388).

Lambotte's bone *spikes* are likewise useful (Fig. 1389).

Screws alone are useful in holding certain fractures reduced where only a point pressure is needed. Lambotte's screws are effective (Fig. 1390). More often beef bone screws (Henderson) or screws of ivory (Magnuson), if fashioned carefully and introduced slowly into well drilled and tapped holes, will prove effective. Sherman's screws are made long for certain fractures. Because of their perfect construction these are the most desirable and suitable screws to be used.

Archibald Young employs successfully *small round nails* of suitable length. He has found them useful in fractures of the bones of the forearm, fractures of metacarpal bones, and even of the phalanges. These fine pins or nails are easily introduced, cause the minimum amount of damage, and do not split the fine delicate fragments (p. 982).

There are certain phalangeal fractures with poor union which have been neglected, causing considerable disability, which Young has been able to refreshen and straighten to great advantage. One such case is seen illustrated in Fig. 650.

The Use of Steel Plate and Screws.—The employment of metal in some form to hold the tissues of the body fixed following various operative pro-

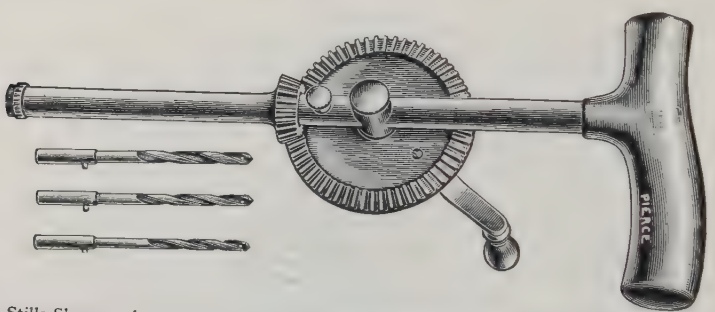


Fig. 1393.—Stille-Sherman bone drill. A powerful instrument adequate for the ordinary drilling of bone.

cedures extends over many years. Fabricious in 1647 and Icart in 1775 used metallic materials for suture in the soft parts and in bone respectively Lane revived the experimental use of steel in fracture treatment.

Operation: Use of Steel Plate and Screws.—The method of using the steel plate and screws in fracture treatment is described in Chapter XXII, p. 758. It is a simple method. If used with care it is an effective method under certain conditions. The Sherman vanadium steel plate and screws are the most satisfactory of any plates and screws yet devised.

The Sherman Vanadium Steel Plate.—This plate combines extreme lightness with toughness and elasticity. The amount of steel in the plate, its exact shape, the number of holes for screws, all have been carefully arrived at by much study and experimentation (Fig. 1395).

The Sherman plate will bend and ordinarily not break. The strength of the plate is due to the fact that it is made of an alloy vanadium steel and not a high carbon hard steel. The plate is slightly curved in its transverse diam-

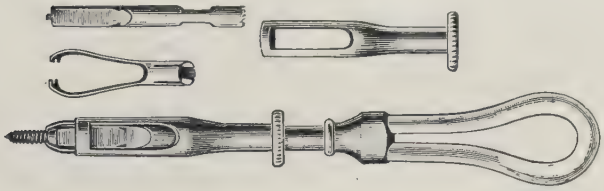


Fig. 1394.—Sherman's combined screw-holder and driver.

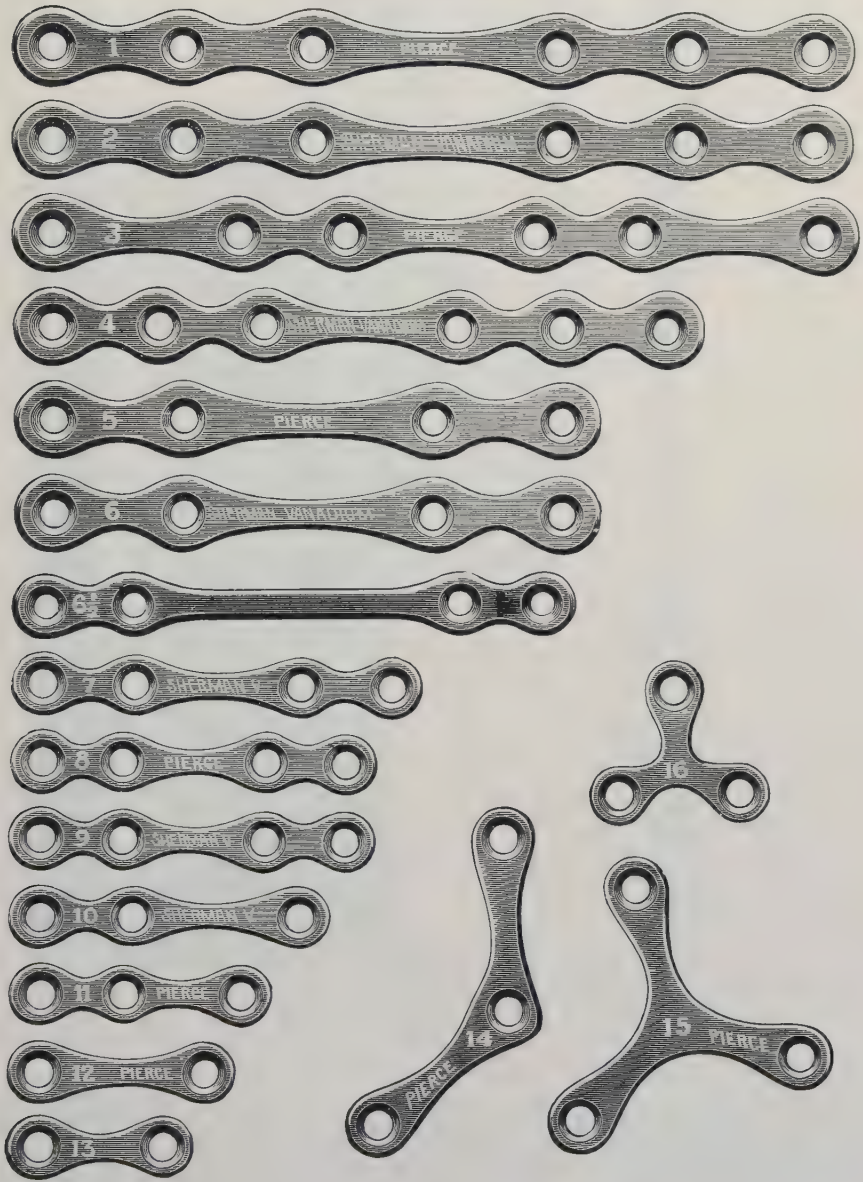


Fig. 1395.—Sherman vanadium steel bone plates. This illustrates the set of plates commonly used.

eter and is for this reason more easily and accurately adjusted to the slightly rounded surface of the bone.

The Sherman Vanadium Tap Screw.—The success or failure of the operation of using a plate in a fracture of bone may depend upon several factors, but one of the most important is that the materials used, plate and screws, be adapted to that for which they are employed.

The *Sherman screw* is a machine screw. It is suited to the work to be done by it.

Fig. 1396.—Full size six-hole Sherman plate.

Fig. 1397.—The Harte retractor and spatula. Used in operations on the shaft of long bones, particularly of the femur (see p. 756). Note roughened serrated surface at end.

The wood screw is conical in shape; its distal two threads do not engage. The flange is variable in size. The steel of the carpenter or wood screw is not uniform in quality, at times it is soft steel, the threads of thin strips; the screw then acts as a short plug, not as a screw.

The Sherman screw contains three flutes on the end-cutting surface, which act as a tap and without which it would be quite impossible to drive home the screw. The tap-cut screw has a machine-cut head which affords a great purchase because of the rounded head. The under side of the head is tapered and fits the shallow countersink provided in the plate. Fewer screws are, therefore, needed with this construction (Fig. 1399).

Fig. 1398.—Fracture of the shaft of the femur in the upper third. Open operation. German silver plate used and wood screws, after the Lane pattern. Note the bending of the plate, the breaking of a screw, and the loosening and pulling out of screws. This illustrates well the inefficiency of the Lane type of screw and the weakness of silver plates (Sherman).

The screw has a small inner center punch which is driven part way into the shaft of the screw which includes the head. This center punch together with the slot enables the surgeon using the Sherman screw-driver to secure a direct drive in inserting the screw without a wobbling of the screw.

The plates and screws should always be carefully inspected previous to being selected for final sterilization.

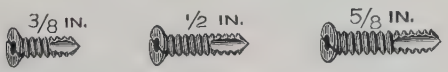


Fig. 1399.—Sherman tap screws illustrating three commonly used sizes.

Defects in construction may be found in screw or plate. A small burr or a little throw-up is found at the end of the screw when the flutes or slots are put in. Instead of the tap acting as a tap and providing a suitable place for the screw, the screw acts as a reamer making the drill hole larger than necessary. The screw fails to engage properly. The screws are designed with a small head, consequently, the plate may be thin and it is not weakened. The screw has 32 threads per inch. (See drawings of the two kinds of screws,

Figs. 1401, 1402). The screw is $\frac{9}{64}$ inch in size. The drills used are $\frac{6}{64}$ inch, commonly known as the Brown-Sharp 32 standard drill. The screw, therefore, is $\frac{3}{64}$ inch larger than

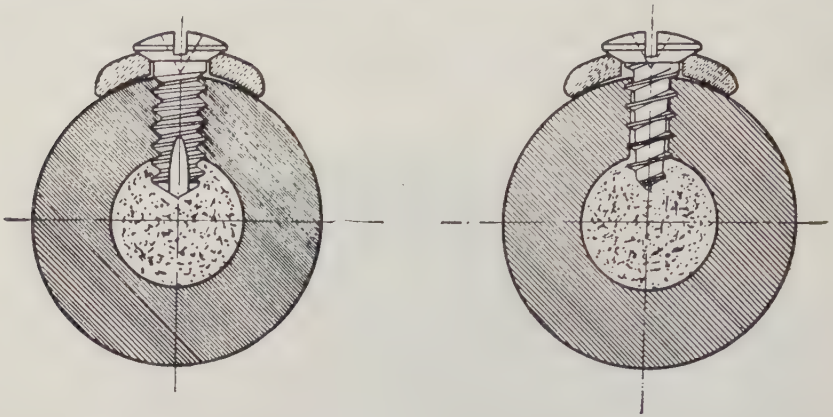


Fig. 1400.—Showing machine screw (on the left) and wood screw (on the right) in position: Greater holding power of machine screw (after Hey-Groves).

the drill. This means that the thread produced by the tap is $\frac{3}{64}$ inch deep. The purchase, therefore, of these screws is very great on the bone (Sherman).

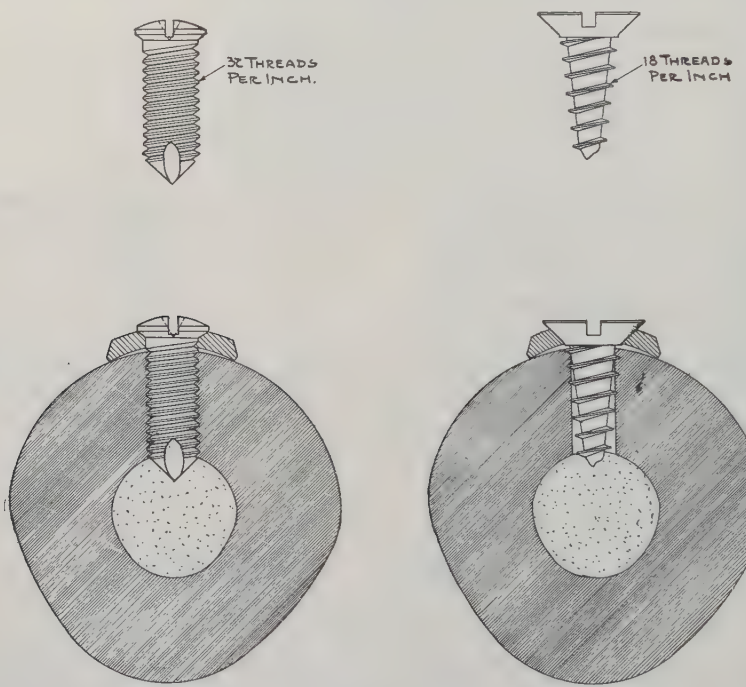


Fig. 1401.—Drawings to illustrate and to compare the steel and wood screws as used in bone (Sherman).

In fractures of the femur Sherman is using, and I believe this is wise, two screws which pass through both cortical parts of the bone—two through

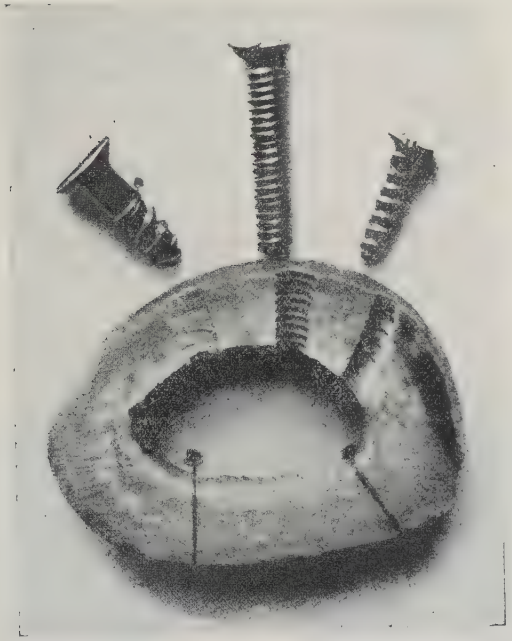


Fig. 1402.—Showing the action of wood and metal screws. The bone has been drilled and screwed by three screws: the left-hand one, an ordinary carpenter's screw; the right-hand one, a Lane screw; and the center one, a metal screw. The wood screws make only a faint spiral groove in the bone, while the metal screw thread lies in a deep slot cut for its reception. (After Hey-Groves, Modern Methods of Treating Fractures, p. 176.)

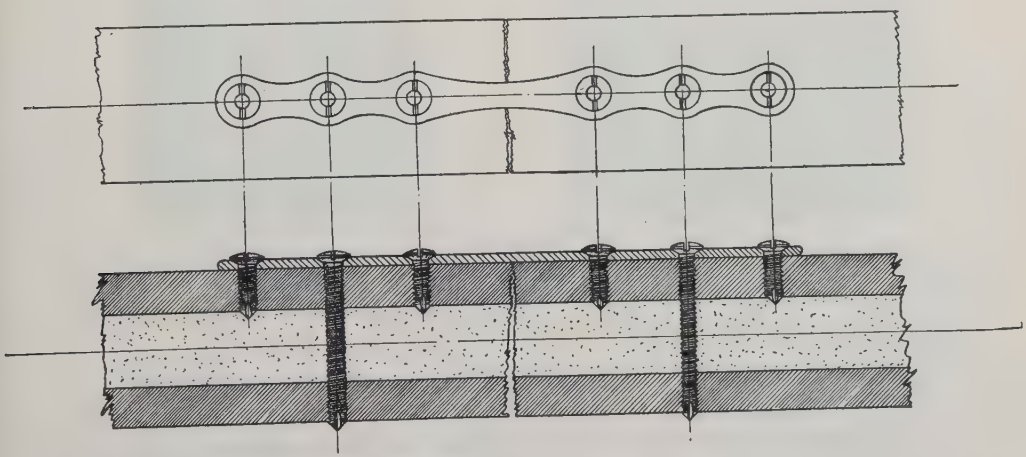


Fig. 1403.—A diagram showing a Sherman plate and screws applied ideally to a fracture of a long bone. The correct place at which to place the screws which transfix both cortical layers of bone is indicated as equally distant from the line of fracture (Sherman).

screws. These are seen in Fig. 1403. The greatest stability at the seat of fracture enables the surgeon to institute early active movement far sooner than when less secure shorter screws are used. These transfixion screws, which have a hold on the two cortical layers of the bone, placed equidistant from

the line of fracture provide a maximum fixation with a minimum number of screws. No additional plate is needed for security in such cases.

A steel plate and screws applied to the surface of a long bone are, of course, foreign bodies. The plate and screws are used primarily to hold bone fragments in direct contact and immovable.

The use of a steel plate and screws in the treatment of a simple closed fracture of the shaft of a bone is followed ordinarily by union of the fracture.

Certain disadvantages said to follow the use of a steel plate:

1. Delayed or non-union.
2. Sepsis of a low grade.
3. Rarefying osteitis or softening of bone in the screw holes.

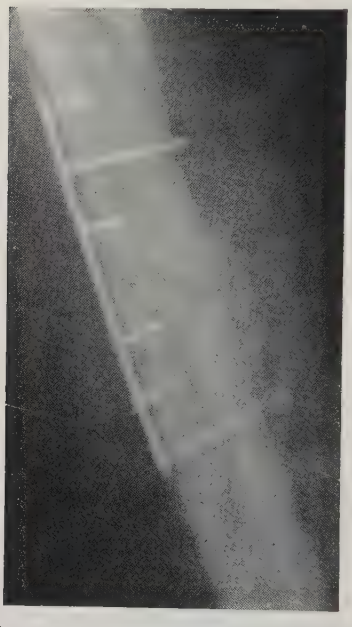


Fig. 1404.—Fracture (closed) of femur in a muscular well-developed young adult. Operation; perfect reposition; steel plate used as seen in Roentgen ray. Note exact reduction of fracture and the two long screws, one placed either side of the fracture. These screws, penetrating the cortex twice, serve to increase immobilization (O'Neil Sherman).

Fig. 1405.—Fracture of shaft of femur. Sherman bone plate with Sherman screws. Note the use of two long screws penetrating the cortex opposite the site of the plate. Firm enveloping callus (O'Neil Sherman).

(1) Delayed Union: The degree of union will be determined largely by the security of the fixation of the fragments. If a limb with a fracture is left entirely alone and untreated, eventually muscular equilibrium will become established. Tension will be at an end. The fracture will heal by a granulation tissue callus. If fractured bones are fastened together by operation loosely, motion being allowed at the seat of fracture, muscle tension is constantly acting and, consequently, union is delayed. If the fragments of a fracture are fixed absolutely solidly so that there is no motion between them

and they are in close contact, union will take place by first intention with a minimum of callus formation. Perfect fixation of a fracture may occasionally be followed by delay in union. This is due probably to an interference with the blood-supply of the bone, either the periosteal, medullary, or the Haversian vessels of cortical firm bone being involved. Delay in union is not ordinarily dependent upon the proper employment of a steel plate for purposes of fixation.

The frequency of the occurrence of a diminished callus following plating as compared with union after the non-operative treatment is common knowledge. The diminished callus at the situation of the plate is not necessarily an occasion for delay in union of the fragments. The inhibitory action of the metal plate on the processes of bone regeneration has been emphasized. At times the part underneath the plate is found to be necrotic, dead, rarefied (Leriche and Policard). Rarefaction about a screw holding a plate has been noted under certain conditions (see p. 784).

The firm application of a steel plate by screws to a bone is said to lower the resistance of these soft tissues involved including the hard bone. The necessary loosening of muscles some distance about the fracture to permit proper retraction of the soft tissues and access to the fracture causes considerable trauma and consequent severe reaction in the process of repair. The mechanical bearing surface of the plate in holding the fragments is the combined machined screw threads pressing against the tap in the bone. This is an efficient hold for a limited time.

Because poor results and difficulties such as those mentioned sometimes follow the misuse of plates and screws, this should not be allowed to militate against the proper employment of plates and screws when indicated.

(2) Sepsis After Plating: If a plate is attached to a bone in such a way that slight but constantly recurring movement is permitted, it may cause mechanical irritation, bone absorption, fluid collection, sinus formation, and finally sepsis, especially if the plate is situated superficially, as under the skin overlying the tibia.

If there is no tension on the screws other than that dependent on the presence of the screw in the bone tissues, the screws and plate will remain in the tissues indefinitely. No rarefying osteitis eventually necessitating removal of the screws and plate will occur.

If, on the other hand, tension or stress is exerted on the screws because the fragments are not adequately supported and steadied by impaction or external splinting; if, in other words, the fragments are unbalanced, the bone tissue reacts to the continuous pressure, the screws become loosened and a rarefying osteitis occurs about the screws. It may be absolutely necessary to remove such screws and plate.

Sepsis is due to something besides the presence in the part of a sterile plate and screws; something besides an error in the operative technic of sterilization—it is due to the faulty fixation of the bone, hence the sequence of events just mentioned—motion, irritation, absorption of bone, fluid collection, sinus formation, sepsis. Indifferent aseptic foreign plates do no harm in the

tissues. Sepsis is often the result and not the cause of inefficient mechanical fixation.

(3) Osteitis After Plating: Considerable investigative work has been done on the behavior of the tissues, the reaction of the tissues to the presence of metallic foreign bodies. The experimental work of Zierold[1] in this connection is a valuable contribution to this subject. Zierold asked the question: Does metal *per se* when implanted in bone exert an influence different from that of any other foreign body? His experiments included the insertion of

Fig. 1406.—Patient fifty-three years old. Fracture of middle of right humerus, seen eleven days later. Operation eighteen days after accident. Four-screw plate used. After ten years perfect function; plate and screws still remain in place, causing no irritation. (Eliason and Hinton, International Clinics, vol. 4, Series 34, December, 1924.)

various metals into the skull, tibia, and ribs of dogs. Holes were drilled in the bones and metal pieces of an exact depth and diameter were firmly inserted.

The microscopical studies of the normal control showed a medullary reaction, likewise a reaction at the site of the cortical defect constant and uniform, but the thickness of the layer of new subperiosteal bone exhibited a variability. Both high carbon and low carbon steel when implanted in bone

[1] Archives of Surgery, September, 1924, vol. ix, pp. 365–412.

provoke the same type of reaction. The metal is incompletely surrounded by a thick zone of cellular connective tissue. Its outer end is free and uncovered by any periosteum. The new bone production in the medulla is negligible, while in the cortical defect it is more scanty than in any of the other specimens, failing to approach the metal by a considerable distance.

The section from the stellite implant shows the least departure from the normal. The type of reaction is similar and the degree is not outside the limits observed in the controls. Moreover, the new bone is so closely laid

Fig. 1407.—Patient twenty-nine years old. Compound fracture of left lower leg in lower and middle thirds. Operation fourteen days after accident. Four-screw steel plate used. Fourteen years after operation the plate and screws remain in position. The leg is functionally normal. (Eliason and Hinton, International Clinics, vol. 4, Series 34, December, 1924.)

down about the metal that if a corresponding area should be blotted out of the control section they could not be identified.

In fact, it appears in this section that the metal merely occupies space affecting in no way the regeneration of the bone and periosteum.

In the different types of tissues examined in the experiments there is a uniformity at least in the manner if not in the degree of reaction to the various metal implants, except in the second series involving the ribs. Here fracture of the bone at the point of injury had added a new and modifying

factor in the mobility of the parts, and it is well to note that in each instance the fracture is attended by an excessive bony overgrowth, which does not correspond to the findings in the other series. Consequently, it may be taken that the movement of the part is responsible for the bone stimulation and not the presence of the metal.

Bone is indifferent to the implantation of some metals and sensitive to the implantation of others. In the first group the metal remains unchanged during its placement in the tissues, while in the second group there is defi-

Fig. 1408.—Patient twenty-five years old. Compound fracture of middle third of the right tibia and fibula. Immediately reduced and steel plate applied to the tibia. Convalescence was without incident. After eleven years the plate is still present and there is no evidence of rarefaction of the bone. (Eliason and Hinton, International Clinics, vol. 4, Series 34, December, 1924.)

nite evidence of varying degrees of corrosion. All other experimental factors being uniform, the only conclusion permissible is that the tissue reaction depends to a great extent on the disintegration of the metal.

LeFort's observation on the tolerance of the tissues to metallic masses is that when the mass is non-septic, non-irritating by its anatomical location or form or chemical nature, the organism tends to ignore it and the phenomena of defense do not appear. The usual reaction is the encapsulation in a dense wall of fibrous tissue.

Removal of the steel plate after it has accomplished the object for which it was used: I believe that the steel plate should be removed from the bone as soon as it is proved that union of the fragments is sufficiently firm to be held by callus.

Granting that steel plates properly applied cause none of the conditions sometimes ascribed to them, such as infections, sinuses, pain, delayed union, danger of refracture, excessive callus, osteitis, even supposing that none of these conditions is caused directly by the plate and screws, the question still

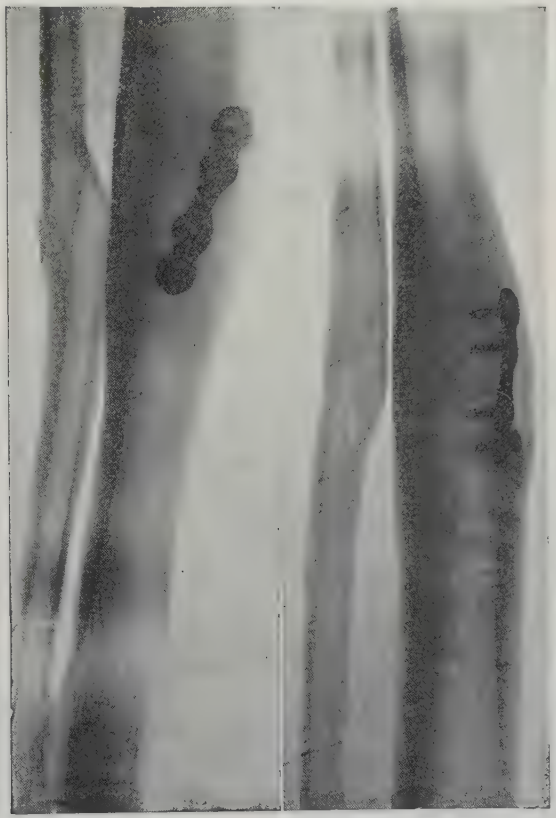


Fig. 1409.—Patient eighteen years old. Fracture of both bones of the left leg. Eighteen days subsequently tibia fracture reduced and a steel plate applied. After six and a half years the above *x*-ray shows the plate in place and no local disturbance in the bone about it. (Eliason and Hinton, International Clinics, vol. 4, Series 34, December, 1924.)

may be asked properly if the plate is applied primarily to hold fragments fixed and in apposition, why should the plate be left *in situ* after it has done its duty, accomplished its special object? It may not be necessary to remove the plate especially when it is seated under cover of muscle masses, but, in my judgment, it is wise to remove it. I believe it should be removed. If the plate is removed none of the difficulties attributable to its presence is likely to occur, for it is by the long-continued presence of the plate that most of the troubles are caused.

Fig. 1410.—Patient forty-one years old. A right Pott's fracture with dislocation of the foot posteriorly. Four days later plate applied to the fibula. After ten years the embedded plate is seen. The plate causes no trouble. Twenty degrees of motion at ankle. (Eliason and Hinton, International Clinics, vol. 4, Series 34, December, 1924.)

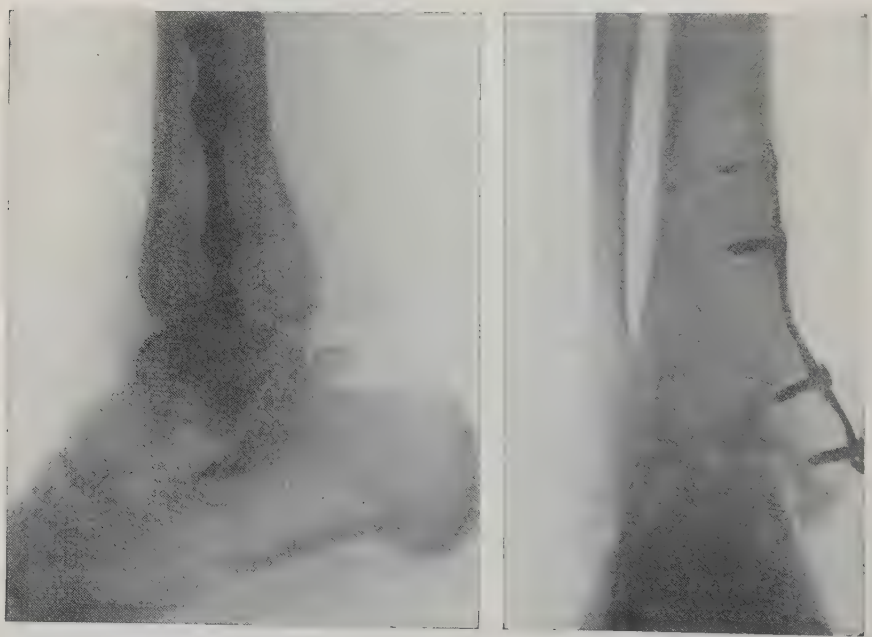


Fig. 1411.—Patient thirty-three years old. Fracture of lower end of the tibia and astragalus. Operation at once. A plate was applied to the tibia. After six months plate *in situ* and causing no disturbance. (Eliason and Hinton, International Clinics, vol. 4, Series 34, December, 1924.)

Illustrations are here shown of the *tolerance of steel plates* for six and one-half, ten, thirteen, fourteen years respectively (see Figs. 1406–1411). These illustrations of tolerance, of course, can be duplicated ad libitum. If a plate and screws are tolerated by tissues when applied in a certain fashion and

under certain controllable conditions, then, if these conditions are repeated, the same tolerance will be manifest. Obviously, it is the duty of the surgeon to reproduce at each operation in which it is necessary to use steel plates and screws the exact conditions which permit such use innocuously without harm. I have attempted to state the conditions as far as known today which permit of the safe use of steel plates and screws.

The Use of Ivory (Magnuson).—This method introduced by Magnuson several years ago (1909) and here described by him has given remarkable and ideal results. It is a mechanical method, simple, sound in principle, requiring special skill, special instruments, and is only to be used by surgeons of experience. I commend it as a method worthy of being acquired. Briefly, the method may be described as the fitting of an ivory key into a keyway in the shaft of the bone—the strongest form of mechanical union of shafts.

THE USE OF IVORY FOR INTERNAL FIXATION (MAGNUSON'S METHOD)

The use of ivory has distinct advantages over other materials for holding bones in apposition.

1. It is an animal tissue which is very strong, much stronger than beef bone of a given thickness. 2. It is slowly absorbable in a very large percentage of cases; in cases in which it is not absorbed it is the fault of the ivory rather than of the tissues. Fresh, green ivory is absorbed. Hard, old, dry ivory does not seem to be absorbed. Neither variety, however, causes any irritation of the tissues with which it comes in contact. The *x*-rays taken of bones in which ivory has been used show that there is sometimes a slight softening of the tissues immediately surrounding the ivory, at least, they have the appearance of decalcification after the ivory has been in place from six weeks to three months. But in no case has the ivory allowed motion between the fragments to a degree sufficient to interfere with holding the fractured bone absolutely in line or allowing the fragment to slip.

Ivory Removed from Clean Cases Postoperatively.—Magnuson has removed four pieces of ivory from clean cases; three have been ivory pegs which in 2 cases were used to hold an internal malleolus in contact with the lower end of the tibia; in another case the peg was put in obliquely through two fragments of a comminuted fracture of the clavicle.

In these 3 cases the peg loosened enough so that it slipped out under the skin, which was very superficial, of course, and the end of the peg could be felt. There was no fluid around the protruding peg, no infection, and no redness of the skin. It was due rather to mechanical irritation of the superficial tissues on account of the thin nature of the covering of the bone, rather than an actual irritation of the ivory itself. They were all removed within three months after the operation. There was no absorption in any of them, and they were easily removed; although they could not be moved sideways in the hole in which they were situated, the smoothness of the surface allowed them to slip out easily.

In the fourth case he had used two plates, one in the radius and one in the ulna, in a case of fracture of both bones of the forearm, between the pronators and supinators. The radius healed; the ulna did not. Subsequently he did a bone graft in the ulna and at that time removed the plate. It was not, however, on account of any irritation caused by the plate. The tissues were not edematous. The ivory was rather soft and felt almost like gelatin which had been allowed to get very, very hard. It had a translucency, and when removed in all of the cases it could be bent to a surprising degree.

He has had an opportunity to see other bones which had had ivory placed in them at varying periods of from one to three years. In one case he had made a bone-graft on the ulna as described (Internal Splinting of Bone, Northwest Medicine, December, 1920), the graft took, and a year and a half later the patient, having used the arm freely in the interim, reinjured it, breaking the graft in the middle, at the point of former fracture

where there had been poor filling in between the ends of the fragments, but good union of the graft to both fragments. In this case he could find no trace of the screws; the graft had solidly united at both ends, and at the point where he knew the screws had been placed there was simply a little heaping up of bone.

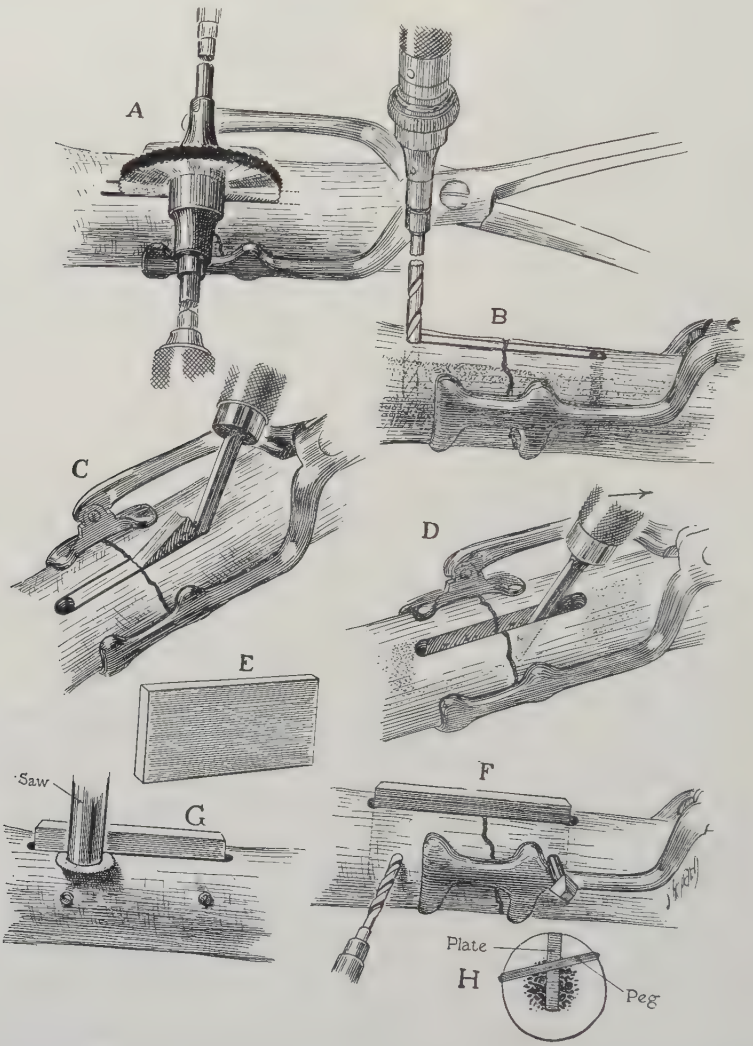


Fig. 1412.—Magnuson's method of procedure in the insertion of the ivory splint or key as a splint in fractures of bone: A, Note bone-holding clamp out of the way of the saw; parallel bladed saw outlining and cutting bed for ivory insert. B, Drilling at either end of the parallel saw cut to free the bed. C, Lifting out the respective parts of the bed. D, Clearing and freeing of all detritus well into medulla. E, The ivory insert. F, The ivory insert in place. Drilling a hole for reception of the peg to hold the insert. Peg seen *in situ* in one fragment and hole being drilled in other fragment. G, Excess or projecting ivory plate being removed flush with the cortex. H, Cross-section showing bone, ivory insert, and peg completely placed. (Magnuson.)

In another case in which there had been used an ivory screw to hold the head of the humerus in apposition to the shaft after a malunited fracture at the surgical neck, he operated about six months subsequent to the first operation to remove considerable amount

of callus which was blocking the forward motion of the shoulder. There had been no trouble from the ivory screw used, but being one of the first cases he had an opportunity to see, he took out a section of bone which contained the screw. This could be done in this case without damaging the patient or his result in the least. At that time he found the screw in solid contact with the bone on all sides, and absorption beginning to occur. There were osteoclasts lying in close contact with the ivory, and toward the medullary cavity there was some granulation tissue absorption.

The advantages of ivory are as follows:

1. It is a slowly absorbable material.

2. It does not irritate either bone or soft tissues unless it protrudes into the soft tissues at a point where they can be pinched between some hard external object and the protruding ivory.

3. *It is stronger than any other material which has been used to retain fragments of bone in position except steel, and does not cause the atrophy of bone cells immediately surrounding it as may steel,* at least, not to a sufficient extent to allow undue movement between the fragments.

4. On account of the method used it fits snugly and absorbs enough fluid from the surrounding tissues so that within twenty-four hours it fits more tightly than was the case at the time of insertion.

5. On account of the absorption of fluids it becomes reasonably flexible, does not retain any brittle qualities, and consequently will give considerably without breaking. It is probably this flexible quality as much as anything else that makes it so kind to the surrounding bone.

Principles Underlying Use of Ivory by Magnuson Method.—The methods used are all based on the most accepted mechanical and engineering principles. The *plates* are not to be confused with the ordinary bone plate or steel plate which is screwed on the outside of the bone. There are two sizes of plates, and these should be called *ivory keys* rather than ivory plates because they are set in as a key in a key-way, which is the strongest form of mechanical union in shafts. They are not screwed on the outside; consequently they are braced on all sides by bone, and form an integral part of the bone, preventing any angulation. The large plates measure $1\frac{3}{4}$ inches long, $\frac{5}{16}$ inch wide, $\frac{1}{8}$ inch thick; the small ones, $1\frac{1}{2}$ inches long, $\frac{3}{4}$ inch wide, $\frac{3}{32}$ inch thick. *Plates* are used only in transverse fractures or nearly transverse fractures and their use is not to be confused with the use of ivory screws which have been found much more advantageous than plates in oblique fractures. It is also pointed out that ivory screws are never used in connection with ivory plates or keys. They are separate and distinct in their mechanics and their uses. Ivory plates, the large plates, are used in femurs and tibias, and the small ones in all the other long bones.

The Method of Using Ivory Keys is as Follows (Fig. 1412).—*Fragments* are put into line and clamped with a clamp such as the Magnuson or Hoaglund clamp, which allows a space between the jaws to insert either a bone-graft or a plate without interference from the instrument. *Parallel circular saws* (A), the blades being held at the right distance apart by a washer previously put between them, are used to make two parallel incisions in the bone. These parallel incisions measure *over all* exactly the width of the plate to be used and are parallel to the long axis of the bone.

These parallel incisions are joined at each end by drilling a hole (B), which is easier than chiseling or sawing between the saw cuts. The thin piece of bone remaining between the saw cuts is then lifted out, leaving a slot in the long axis running through one side of the cortex into the medullary cavity.

A *scraping chisel* is then used to smooth off the inner side of the opposite cortex (C); that is, with a scraping motion the rough medullary substance on the opposite side of the

bone and directly underneath the slot is scraped off by running the chisel longitudinally up and down in the slot, the chisel being made just thick enough so that it will fit into this slot; it is used on the principle of a floor scraper.

The *ivory plate* then is driven in edgewise, so that, in case of the large plate, it lies across the fracture $1\frac{3}{4}$ inches long, having about $\frac{7}{8}$ inch on each side of the fracture line, one edge protruding usually beyond the cortex, at the place it was inserted (F and G).

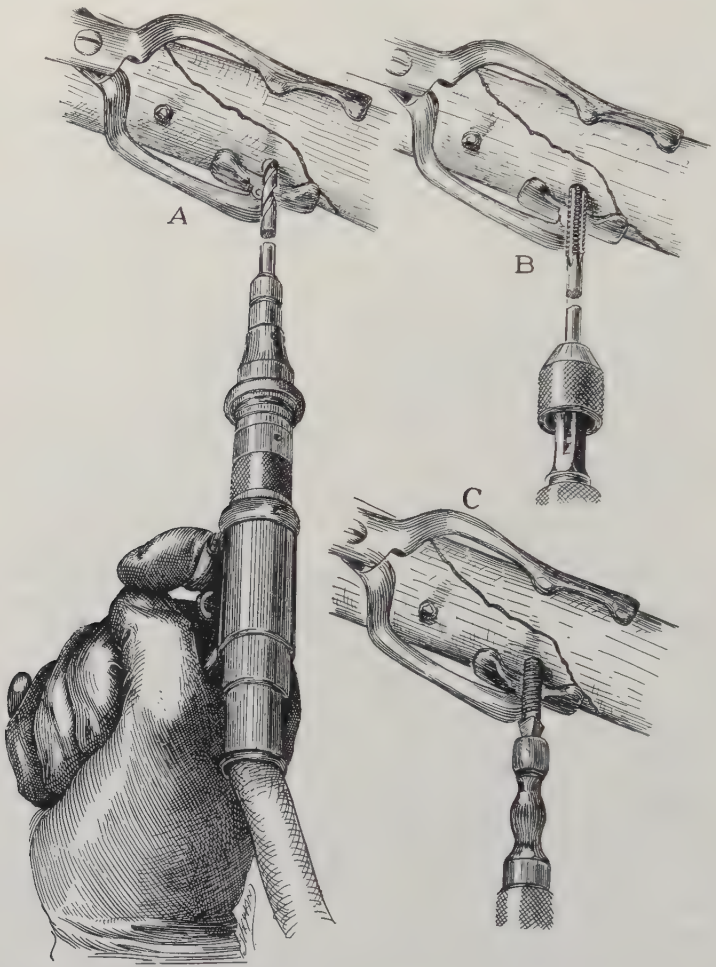


Fig. 1413.—The use of Magnuson's bone clamp: A, The drilling of the hole with the ordinary drill. B, The tapping of the hole with tap screw. C, The introduction of the bone or ivory screw. (Magnuson.)

There is only one plane now in which this fracture can move, and that is in the plane which was taken by the saws in making the cut. It is, therefore, necessary to prevent motion to hold the plate down into this slot or key-way, and a *drill* is provided which will make a hole exactly the size of an ivory pin (peg or nail) (F). With this a hole is drilled through the cortex which lies toward the operator, the end of the plate lying on one side of the fracture line and the cortex opposite from the operator. The drill is withdrawn and an *ivory peg*, which fits this hole perfectly, is inserted (H). This operation is repeated on the opposite side of the fracture line. The pegs need go in at no particular angle except

that most convenient for the operator, but they must lie crosswise to the plate in order to hold the plate down into its slot. The pegs are cut off flush with the cortex of the bone.

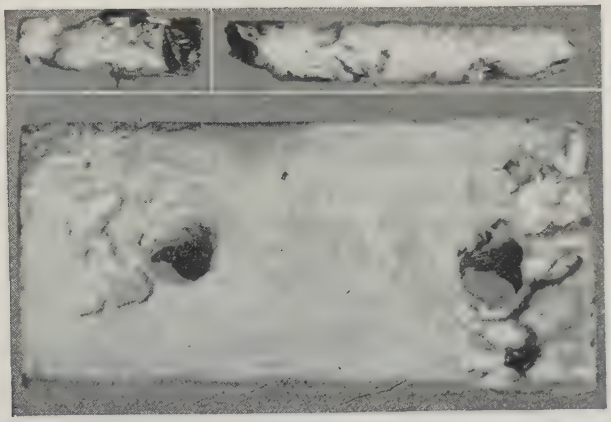


Fig. 1414.—Ivory plate and peg showing absorption effected within three months after insertion. Ivory lasts some time, but is eventually completely absorbed (Magnuson).

There is usually left the edge of the ivory key or plate extending beyond the cortex of the bone. This is removed by using a small circular saw, cutting the plate off flush with the cortex also.

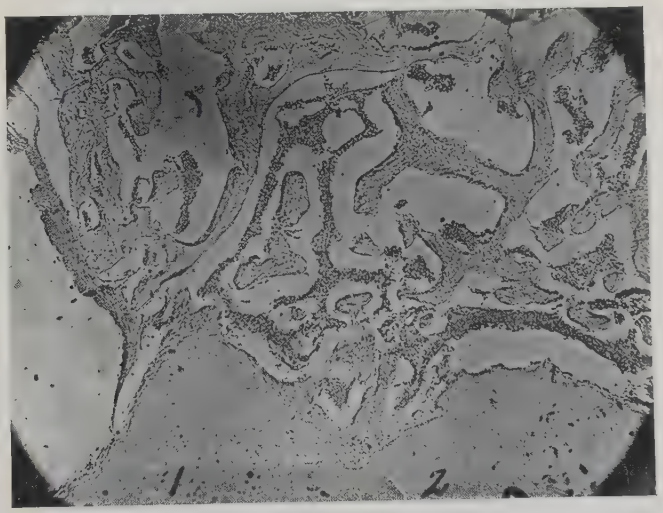


Fig. 1415.—The points of two threads of an ivory screw 1 and 2. Note the new bone growing into the ivory at the base of the threads (Magnuson).

This method is applicable in any transverse or nearly transverse fracture where there is little or no breaking up at the ends of the fragments. It is of no service in comminuted fractures because the plate is not long enough to bridge any considerable comminution and be attached to the main fragments. They could be made longer, but Magnuson thinks that a key is not applicable unless it can be inserted as a key and braced on three sides by the

substance into which it is inserted. Where there is any considerable comminution this cannot be done. Therefore, the mechanical principle on which the operation is based is lost.

Results of Use of Ivory Key (Magnuson).—This method has been used in fractures of the femur for over ten years without a single mishap in the way of having an ivory plate break or having to be removed. Magnuson has not had a single infection in a femur where ivory plates were used, which means that there is no irritation by the substance used and that there has been little damage to either the bone or the soft tissues in its insertion. He is so confident of results in femurs that he has adopted the principle of leaving a full length cast on for ten days to two weeks only, at the end of which time

Fig. 1416.—Fracture of the shaft of the femur in a child eight years old. Impossible to replace. Operation done (Magnuson).

the cast is cut off behind at the level of the flexion fold of the knee and allowed to extend down along the sides about 4 to 6 inches farther, so that it braces the tibia and the knee-joint and prevents lateral motion. The patient is allowed to be up on crutches with a high-soled shoe on the opposite foot. Magnuson operates on all fractures of the femur except compound fractures and those very near the knee-joint by this method.

Knee-joint Disability Following Key Method.—He feels that the disability that occurs in the knee from immobilization is greater and more persistent than any other disability incurred as a result of fracture of the femur. He has had no shortenings, and no infections and no deaths. Ninety per cent. of simple fractures of the femur which he has operated in this way have returned to work within six months, and one case which he recalls went to work as a switchman on a railroad within three months from the date of the

injury, without any disability of the knee or any shortening of the leg. He has never had to remove a plate or a screw from a femur.

There are two *x*-ray pictures of femurs treated in this way. One a man of twenty-two years; the other a child of four.

In view of the results obtained, Magnuson feels that his established asepsis and general technic warrant continuing the use of this method.

Ivory Screws.—This method is extremely simple and the most efficacious method of holding together fragments, either large or comparatively small, firmly and without fear of displacement; the only requisite being that the obliquity to the transverse axis be great enough to allow a screw to be put

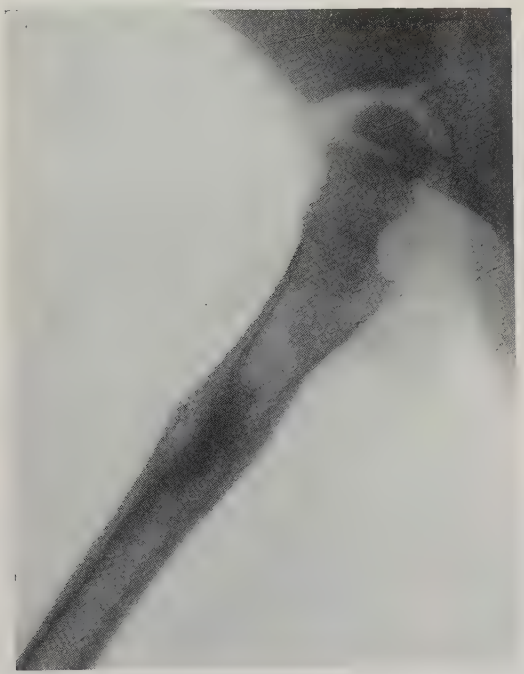


Fig. 1417.—Same femur as that in Fig. 1416. An ivory plate introduced; union solid. Absolutely perfect alignment. Result functionally perfect. *x*-Ray six months later showing shadow of ivory plate and faint shadow of ivory nails, with no rarefaction of bone around them. This plate was put in ten years ago. There has been no irritation and growth has progressed normally. (Magnuson.)

Fig. 1418.—Fracture of shaft of a femur in an adult. An ivory plate inserted as a key, with ivory nails. Fracture of femur immediately after operation. Note faint shadow of ivory plate and faint line of ivory nails (Magnuson).

through from one fragment to another without being at more than a 45 degree angle with the long axis of the bone (see Fig. 1413).

A drill is furnished which makes a hole the diameter of the screw, taken at the base of the threads; that is, it is smaller than the screw by twice the depth of the thread on one side. This hole is put through at any angle to the long axis of the bone, but preferably at some angle between 45 and 90 degrees. A tap is then used to cut threads in the bone exactly the size of the screw to be used. This tap is patterned exactly after the mechanic's tap and is used in the same way. There is one precaution to be taken, and that is, that in holding the tap handle in the operator's hand, the same axis must be main-

tained throughout the cutting of the threads. Otherwise the proximal end of the hole would be enlarged by the sharp, cutting sides of the tap, and instead of a perfectly cylindrical hole there would be a conical hole made which does not allow the firm approximation between the screw and the bone. The tap is removed and an ivory screw, made with a square head and fitting into a socket wrench, is turned in until the point of it approaches the distal cortex of the bone. It is brought to a stop when the point is just through this cortex and the protruding end toward the operator is cut off flush with the bone. In long, oblique fractures two or more of these screws may be used. They come in two sizes, as do the taps and drills, and are as near fool-proof as anything in the mechanical line can be made.

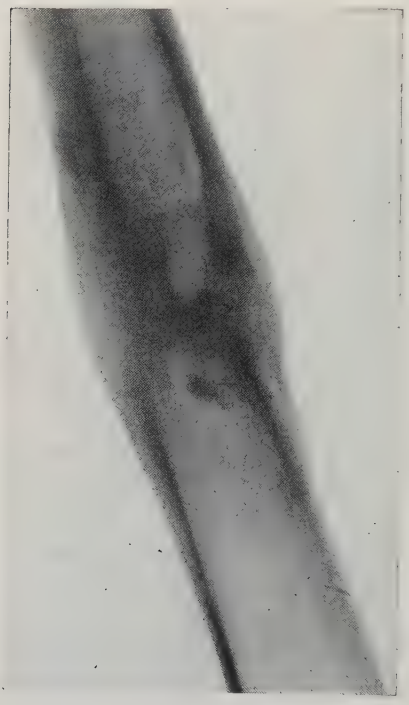


Fig. 1419.—Fracture of the femur. Same case as seen in Fig. 1420, six months later. Note union and alignment and disposition of good callus. Still shows faintly ivory plate and peg; good callus formation covering the plate completely (Magnuson).

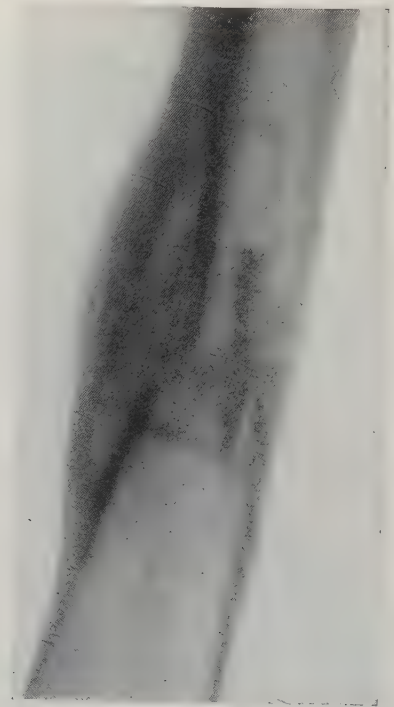


Fig. 1420.—Same femur as seen in Fig. 1419 taken at right angles to that figure. Fracture of femoral shaft. Ivory key plate inserted. Note union and key of ivory *in situ*. Notice ivory nails running through plate at different angles still visible, with no rarefaction of the bone around either plate or nails (Magnuson).

These screws are also used in holding inlay and overlay bone-grafts in approximation, instead of sutures of silk or kangaroo tendon. They hold much more firmly and are much more easily and quickly applied.

The Sterilization of Ivory Plates, Nails, and Screws.—Ivory plates, nails and screws should be sterilized by placing in the autoclave under high steam pressure for one hour. They should be kept in either an air-tight jar or in a room in which moisture is supplied artificially or by nature. Sterilization by chemicals should be avoided, as it makes the ivory brittle. Boiling in water warps and swells the ivory.

CHAPTER XXIV

SURGICAL APPROACHES TO THE BONES

Approaches to bones, seven requisites—**Clavicle**—**Humerus**—Incision—Lower end—Musculospiral nerve—Upper end—Elbow-joint anteriorly—Lower end posteriorly—Lateral approaches—Certain landmarks—**Radius**—Upper end—Head and neck—Lower end—Middle of shaft—Complete exposure, Henry—**Ulna**—Shaft—Olecranon process—**Carpus**—Dorsal and palmar approaches—**Femur**—Approach to hip-joint—Shaft of the femur—Anterolateral approach, Henry—Distal extremity—**Tibia** and **Fibula**—Upper third—Middle third—Lower third.

One factor contributing to the good surgery of fractures is a knowledge on the part of the surgeon of anatomical approaches to the bones and joints. The approaches to other operative fields have been carefully studied and formulated, and the importance to an operative procedure of an appropriate approach is generally appreciated.

The approaches to bone[1] should be: (*a*) Anatomical, that is, should have regard to gross structure and arrangement; (*b*) should be the least damaging to the soft structures; (*c*) should afford easy and ample access to the part involved; (*d*) should preserve when practicable both sensory and motor nerves; (*e*) should avoid injury to muscles; (*f*) should conserve the blood-supply to the part including the nutrient artery of the bone; (*g*) should have regard for fracture fragments (vascular supply, preserving periosteal covering, etc.). The surgeon operating most successfully in any field ordinarily will be the one familiar with non-obviously practical anatomical knowledge. Such knowledge will afford a background for the most intelligent work. In general, with few exceptions, the surgery of the extremities, the operative surgery of fractures, is of a low order of excellence because no intelligent systematic regard for anatomical approaches to fractures has been thought important.

The Clavicle.—Ordinarily access to the clavicle through the conventional direct approach from in front over the bone leaves a cicatrix that may be unsightly. The anterior direct approach may be concealed by very careful suture of the platysma, by using subcutaneous catgut sutures, and great care in approximation of skin edges.

Soutter has suggested an incision for the avoidance of anterior scars in approaching the greater part of the clavicle. It extends from the spine of the scapula forward over the deltoid, up over the shoulder tip just within the outer end of the clavicle. The anterior portion extends down in front just internal to the anterior axillary line and then at right angles 1 inch inward.

[1] J. E. Thompson, Texas, Annals of Surgery, September, 1918; A. K. Henry, Dublin, British Journal of Surgery, vol. xii, No. 45, 1924.

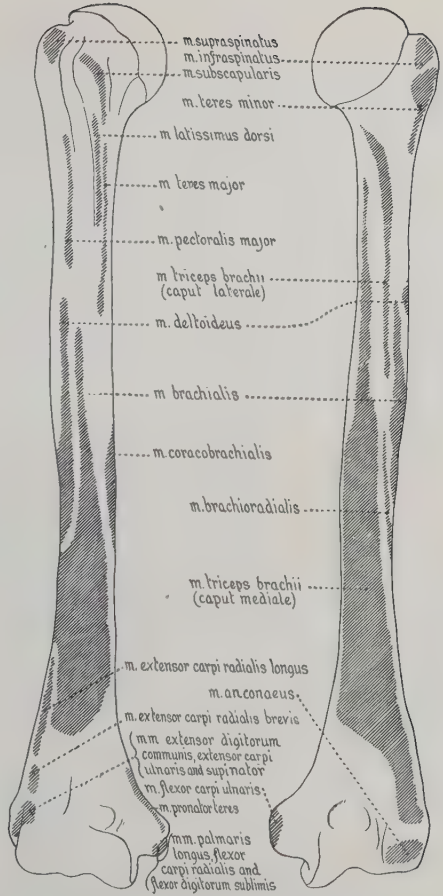


Fig. 1421.—A drawing to be consulted previous to operations for fracture of the humerus. Note the attachments of the several muscles to the humeral shaft (after Spalteholz).

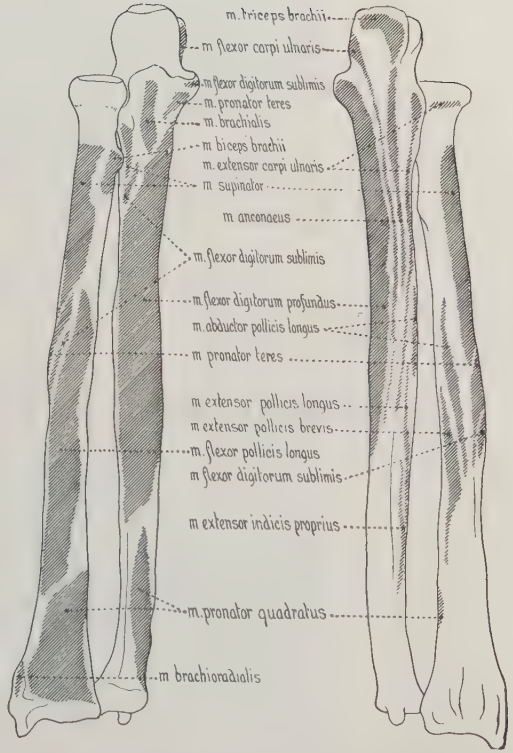


Fig. 1422.—A drawing to be carefully consulted previous to operations on the forearm for fracture. Note the attachments of the several muscles to the radius and ulna (after Spalteholz).

The incision is placed where it may be covered easily by a shoulder strap of the clothing.

The Humerus.—Access to the humerus may be necessary at its (*a*) upper end, (*b*) along the shaft, and (*c*) at its lower end. The method of access here depicted and advocated lays bare the front of the humerus from end to end, having the musculospiral nerve protected and concealed; if further exposure of the nerve is required, the nerve is directly available. The method

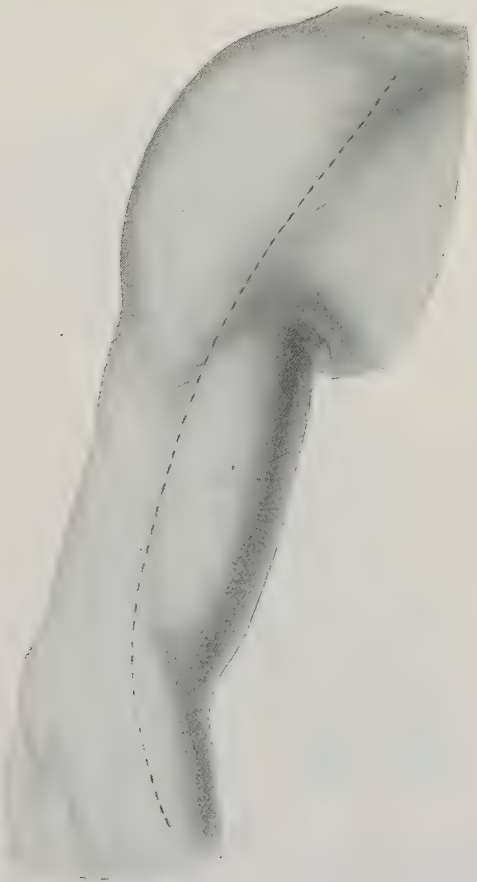


Fig. 1423.—Drawing to show the desirable line of the skin incision in operations approaching the humerus and elbow (after Henry, Dublin).

described respects anatomical structures, gives ample access to the bone, and conserves time and effort (Thompson, Henry).

The Operation.—The patient lies with the limb at the side completely supported. The elbow is extended, when necessary flexed. If desirable the limb may be abducted by an assistant.

Incision.—For exposure of the shaft the skin incision (Fig. 1423) follows essentially the cephalic vein from the tip of the coracoid process to the bend of the elbow, and is continued into the forearm in the middle line

of its upper third. The vein is exposed and the outer edge of the biceps belly defined by dividing the deep fascia on its outer side (Fig. 1424).

To expose the lower distal part of the shaft of the humerus the incision is deepened, dividing the deep fascia. The humeral shaft may be reached at the deltoid border (Figs. 1424 and 1426). The inner three-fourths of the wide brachialis muscle are covered by the biceps belly (Paulet—see Figs. 1421 and 1424). Retraction of the biceps belly mesially will find the brachialis muscle lying on the bone. Divide the brachialis, splitting it to the bone (Fig. 1425). The splitting takes place along the dotted line of the diagram

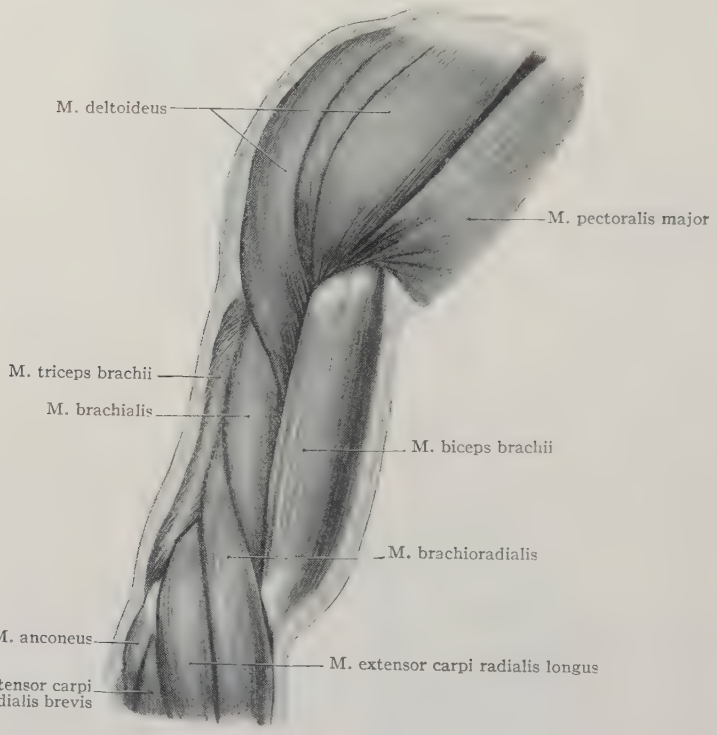


Fig 1424.—Approaches to the humerus. Musculature of the right upper extremity, including shoulder, upper arm, and elbow from the outer side. The uncovered outer fourth of the brachialis appears between the biceps and the brachioradialis and extends behind the pointed deltoid insertion. It can be used as a buffer to protect the radial (musculospiral nerve). See text.

and where the fibers are longitudinal. The outer strip of the brachialis, thus separated, forms a muscular buffer which protects the musculospiral nerve from injury (Fig. 1428). The nerve is not seen if only the front of the humeral shaft is exposed. The back of the shaft likewise can be cleared safely while the nerve remains concealed.

The *musculospiral nerve* (radial) lies about a fingerbreadth below the insertion of the deltoid muscle. The nerve can be found by further mobilizing the brachialis and retracting it backward. It lies in the plane between the brachialis and the brachioradialis. Pulling the brachialis away from the

bone, removes the nerve from contact with the bone so that the periosteal elevator may be passed safely close to the bone without injury to the nerve (see Fig. 1428). The nerve is most lax when the arm is adducted and the elbow flexed to 80 degrees, hence, in this position the nerve is protected. The incision may be carried through the lower part of the brachialis to within two fingerbreadths of the level of the epicondyles without entering the elbow-joint (see Fig. 1426). Flexion of the elbow to a right angle relaxing the

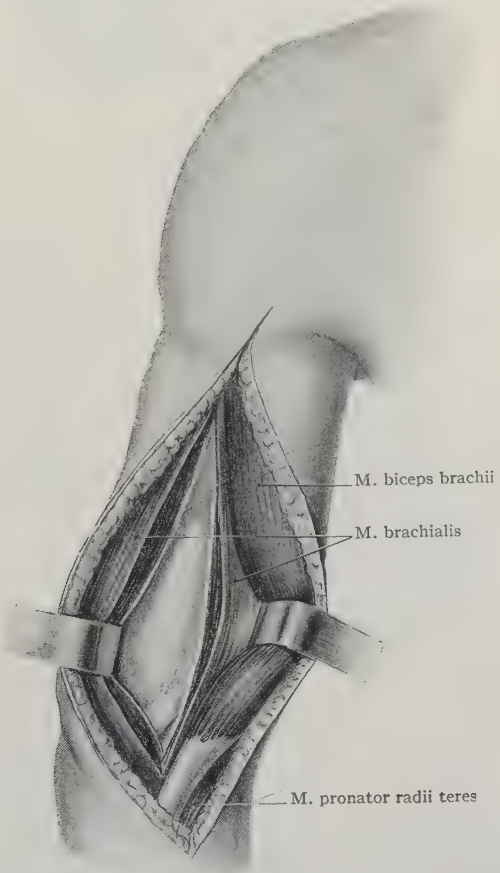


Fig. 1425.—The approach to the anterior surface of the lower fourth of the humerus. Separation of the split brachialis from the bone. By continuing the incision downward sufficiently (see Fig. 1423) an anterior approach to the elbow-joint is provided. (After Henry, Dublin, British Journal of Surgery, vol. xii, No. 45, 1924.)

muscle masses leaves the bone widely accessible through a comparatively shallow wound. The front of the humeral shaft is thus exposed in its entire length. Above, the retraction of the deltoid may be increased by abduction of the arm. Good access to the proximal end of the humerus is not always obtainable.

The *shoulder-joint* and the upper humeral shaft, including the tuberosities, may be exposed by retracting the deltoid fibers outward, but, as Henry points

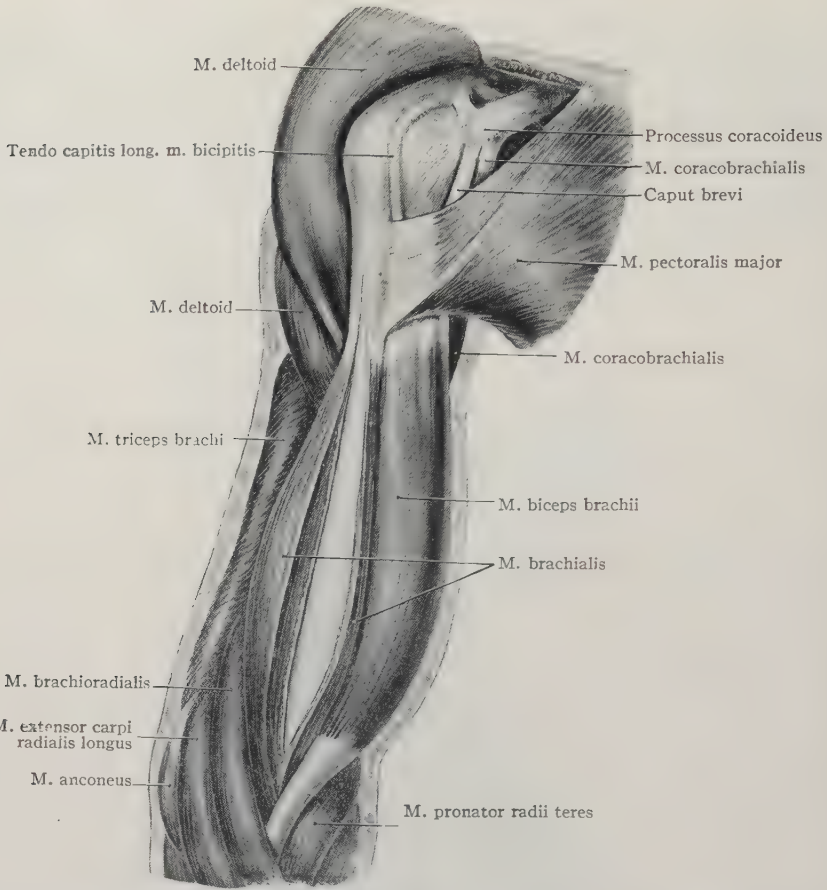


Fig. 1426.—Approach to the humeral shaft. By displacing the deltoid outward by a hinged chip cut from the clavicle (see Fig. 1427) the whole shaft of the humerus will be accessible. By detaching the part of the brachialis which extends behind the deltoid tip the (radial) musculospiral nerve can be found (after Henry Dublin).

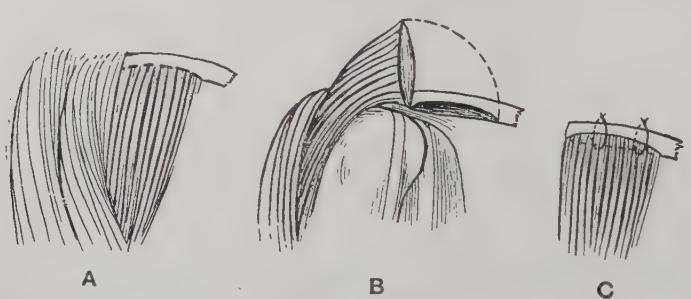


Fig. 1427.—Cut the hinged chip from the clavicle along the dotted line shown in A. B, Turn the deltoid out upon the hinged chip. C, Reconstitute the deltoid origin with two sutures which tie the chip back into place (after Henry, Dublin).

out, the deltoid forms a thick and rather unyielding curtain which when pulled aside gives a grudging revelation of the shoulder-joint. By continuing

the skin incision outward from the coracoid process on the upper surface of the clavicle to the acromioclavicular joint, the skin is reflected, the deltoid

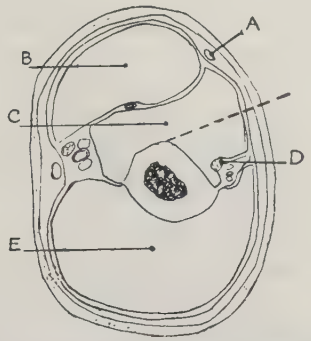


Fig. 1428.—Diagrammatic transverse section of upper arm: A, Cephalic vein; B, biceps; C, brachialis; D musculospiral nerve (radial); E, triceps. (After Henry, Dublin, British Journal of Surgery, xii, 1924.)

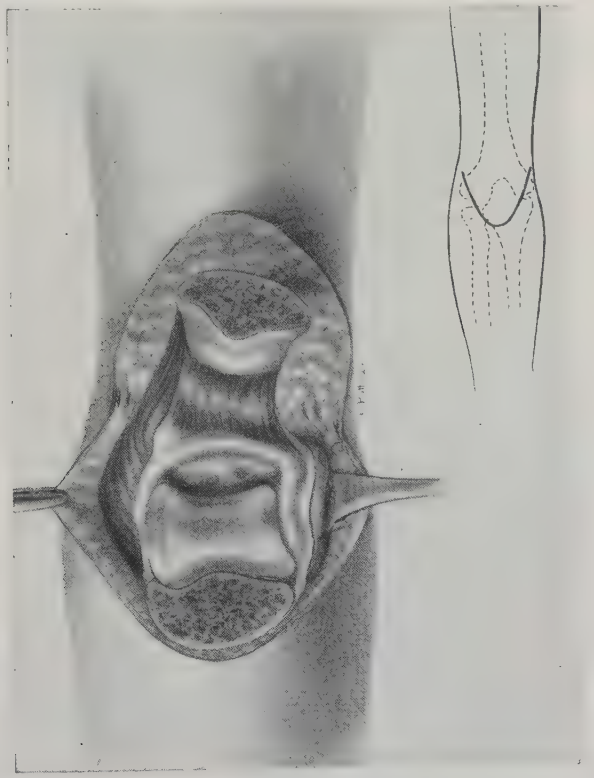


Fig. 1429.—To illustrate a curved incision (see insert) for approaching fractures of the lower end of the humerus which lie close to or enter the joint surface of the humeral trochlear. The ulnar nerve is seen behind the internal condyle. The olecranon process is shown divided transversely. The small fragment is retracted upward.

clavicular origin is developed. Divide the fascia and periosteum on the upper surface of the clavicle. With a chisel detach the edge of bone giving

origin to the deltoid as far as the acromioclavicular joint. The deltoid can then be turned outward on a hinged piece of bone (see Figs. 1426, 1427). An ample view of the upper end of the humerus is thus gained.

The Elbow-joint.—This joint can be approached anteriorly by extending the incision through the brachialis. The tip of the coranoid process and the trochlea become visible and with adequate retraction the head of the radius and the capitellum appear. After completing the bone operation careful extension of the elbow, before suturing the fascia, closes the wide wound in the muscle and renders easier suture placing in the divided edges of the fascia (Fig. 1425).

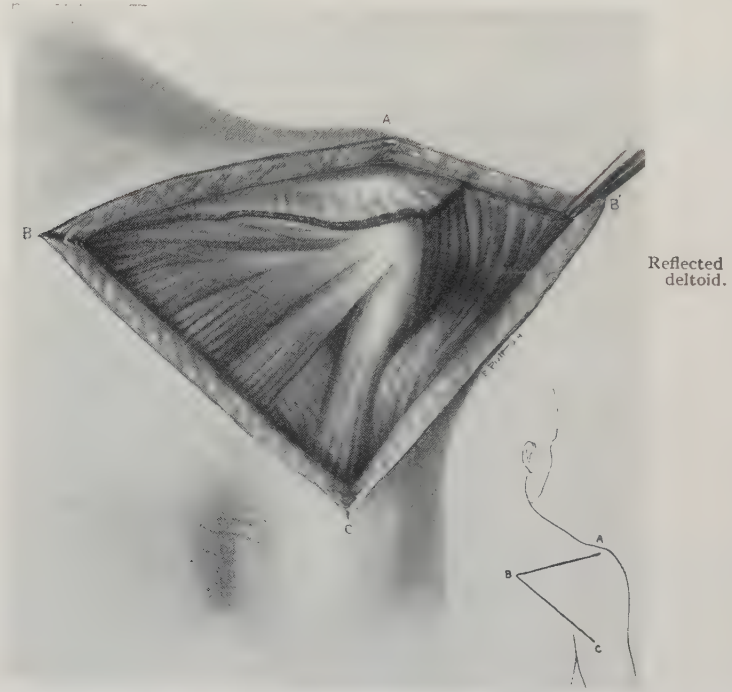


Fig. 1430.—To illustrate the approach to the shoulder from behind by division of the scapular spinal origin of the deltoid fibers. Insert: Note lines (A–B, B–C) of incision. B′ is approximated in suture to B.

The Lower End of the Humerus.—Posteriorly the condylar surface of the humerus is easily reached through a splitting of the triceps muscle. The splitting should be made a little medial to the center of the muscle. Thus, in extending the incision upward there will be a minimum danger in opening the tissues surrounding the musculospiral nerve (see Fig. 1438). This approach facilitates the application of plates and screws in reconstructing the lower end of the bone following T and Y fractures of the joint. Making the median posterior incision a bit lower than the olecranon tip, by division longitudinally of the fibers of the flexor carpi ulnaris and a bit of the anconeus and by peeling these muscles from the medial and lateral surfaces of the olecranon, access to the posterior surface of the humerus is easy.

The Lateral Approach to the Lower End of Humerus.—An incision is made over the external condyle (see Fig. 1434). In skilled hands, separating the brachioradialis and the extensor carpi radialis longior and retracting posteriorly the radialis longior and brevis, the external condyle is well exposed. The nerve supply of the extensor carpi radialis longus must be remembered.

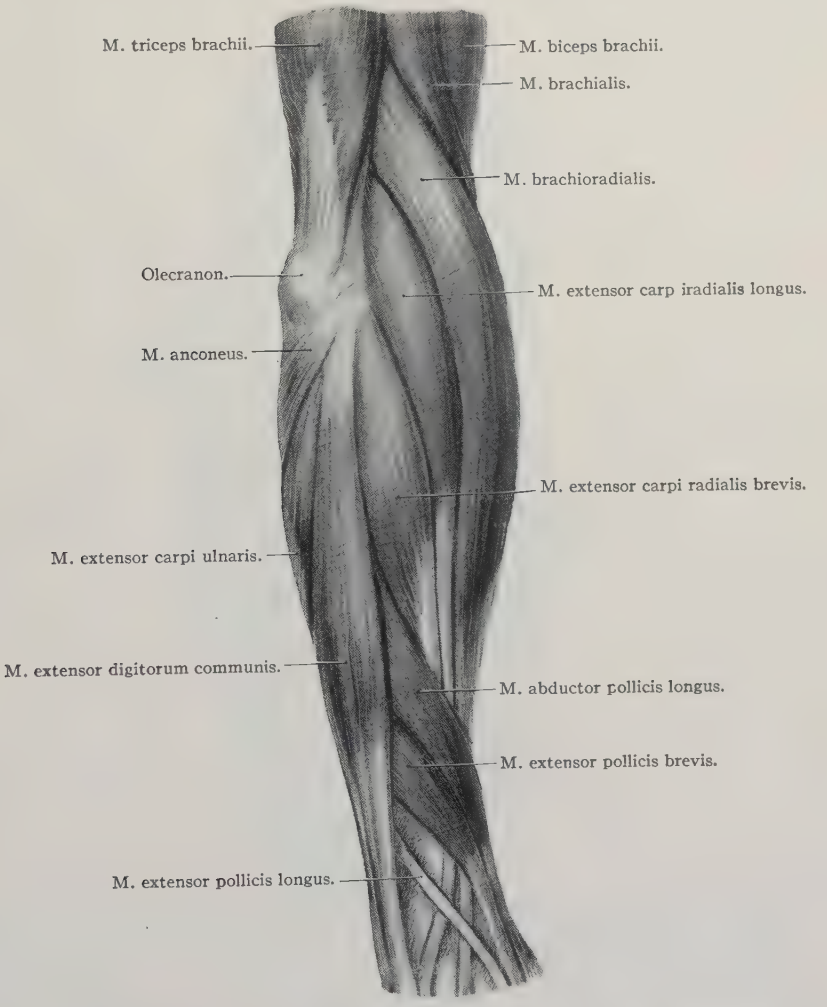


Fig. 1431.—Note musculature of the elbow and forearm and wrist from the outer side. The approach to the humerus and radius is through definite muscle planes.

It may be damaged (Thompson). The *musculospiral nerve* will be seen toward the lateral edge of the condyle, lying beneath the belly of the brachioradialis. The supinator brevis will be seen deep in the wound.

A *more posterior* and *lateral external* approach, which at times is desirable, may be made between the extensor carpi radialis brevis and extensor digitorum communis anteriorly and the extensor carpi ulnaris and anconeus

posteriorly (see Fig. 1432). If it is essential that the external lateral approach should be supplemented by an *internal approach*, a curved incision may be made over the internal condyle to the bone. All muscular origins and attachments may be separated from the bone. The position of the ulnar nerve and its relations must be constantly in mind.

If far greater *access to the humerus* on the outer side is needed than the above approaches permit, the origins of the extensor carpi radialis brevis and

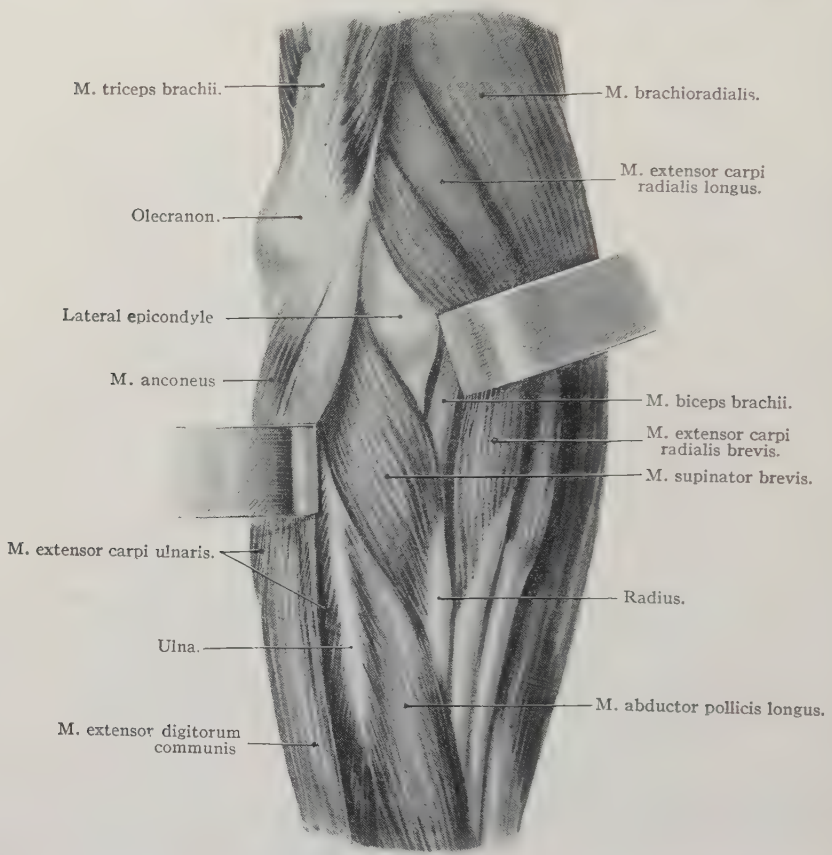


Fig. 1432.—Approach to the outer side of the elbow region. By retracting the extensor carpi radialis longus and brevis anteriorly and by retracting posteriorly the extensor carpi ulnaris and digitorum communis the supinator brevis is exposed, and above it the external condyle.

the extensor carpi radialis longus may be in whole or in part severed or peeled from the bone and retracted (see Fig. 1434).

Certain Landmarks.—The insertion of the deltoid muscle into the lateral aspect of the shaft of the humerus is a bit above the middle of the bone and just above the musculospiral groove (see Fig. 1421).

The musculospiral groove is on the middle third of the shaft of the humerus and lies very obliquely. In it lie the musculospiral nerve and the arteria profunda humeri (see Fig. 573).

A line drawn vertically upward along the middle of the humerus posteriorly would touch the musculospiral groove at a point near the lower part of the deltoid insertion. The nutrient foramen is on the anterior medial surface of the humerus near the insertion of the coracobrachialis.

The posterior aspect of the shaft of the humerus in the neighborhood of the groove should be avoided or approached with care during any operative procedure.

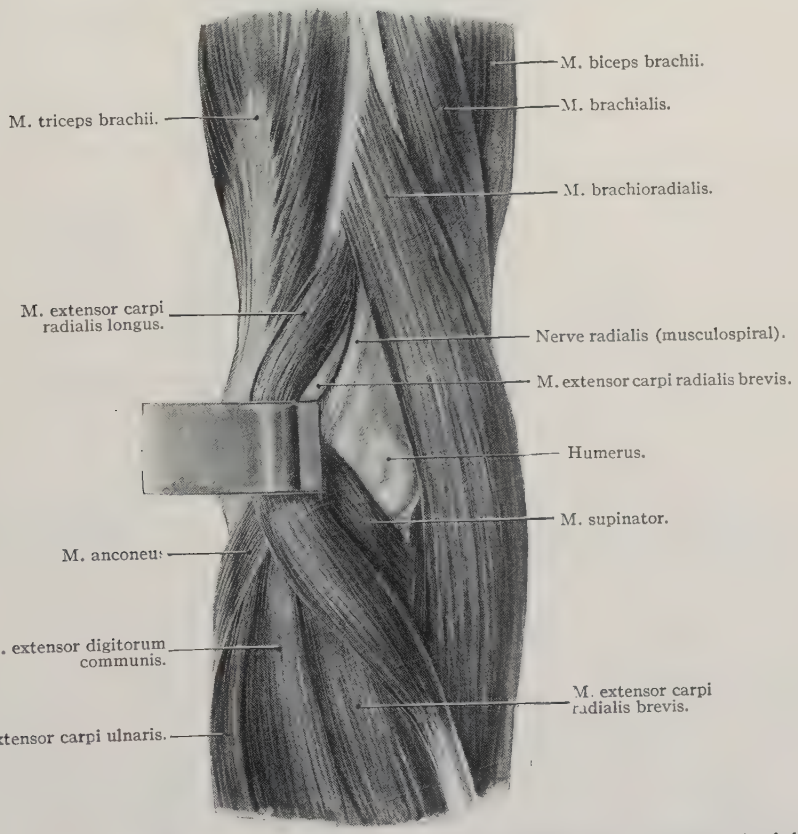


Fig. 1433.—By retracting posteriorly the extensor carpi radial longus and brevis to the outer side of the brachioradialis an approach a bit more anteriorly than that in Fig. 1432 is secured. The (radial) musculospiral nerve is seen between the brachioradialis and the extensor carpi radialis brevis tendon next to the humeral shaft. The lower end of the humeral shaft anteriorly may be cleared and reached with comparative ease (see Fig. 1434).

In the posterior approach to the lower end of the humerus splitting the triceps does not interfere with its nerve supply for it is parallel with the muscle-fibers.

An attempt to approach the humerus through an incision along the posterior border of the deltoid would endanger the vascular and nervous supply to the deltoid.

The splitting or moderate separation of the deltoid fibers on the outer aspect of the shoulder immediately beneath the acromion in approaching the

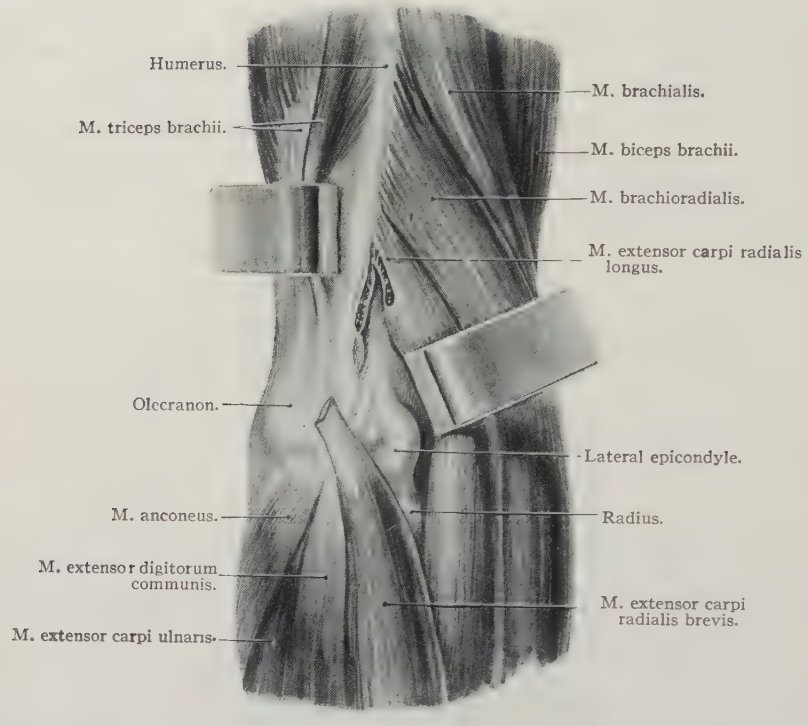


Fig. 1434.—By separating the extensor carpi radialis longus and brevis attachments from the humerus it is possible to gain further access to the lower end of this part of the humerus. This procedure is not often necessary.

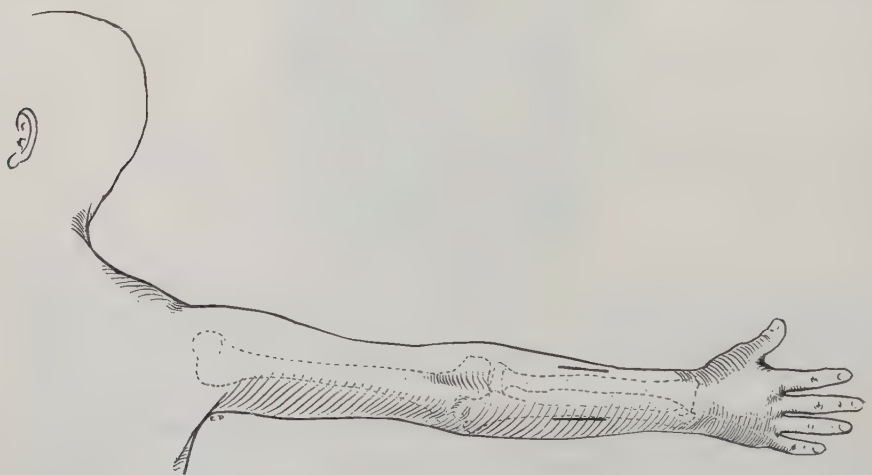


Fig. 1435.—Drawing to illustrate the prone position and slightly posterior, rather than lateral, approaches to the bones of the forearm. Consult Fig. 1441. A desirable operative position.

great tuberosity of the humerus is a useful route. There is a serious objection to it, however; that is, if an extensive incision is made the muscular fibers in front of the incision may atrophy.

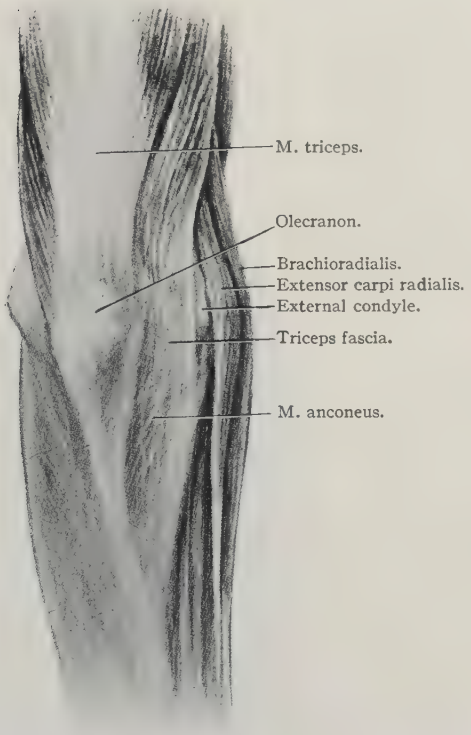


Fig. 1436.—Extensor muscles of the back of the elbow (after Davis-Peotti). Note fascial attachments of the triceps.

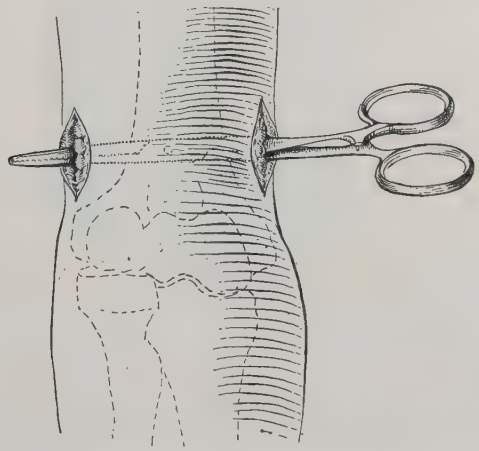


Fig. 1437.—Diagrammatic drawing to illustrate that through the ordinary bilateral condylar incisions at the elbow an instrument may be safely passed to clear the humerus completely across its anterior portion.

The Radius.—An incision carried vertically upward from the styloid process of the radius will expose the brachioradialis tendon of insertion with the radial artery lying medially or on the inner side of it (see Figs. 1490,

1491). The insertion of the tendon of the brachioradialis may be peeled from the bone if necessary. The pronator quadratus will be seen on the anterior surface of the radius, lying beneath the brachioradialis tendon. By retraction of the tendons of the extensor carpi radialis brevis and longus dorsally and the tendons of the abductor pollicis longus and extensor pollicis brevis, even a moderate amount, the whole lower end of the radius may be so exposed as to render easy any operative procedure for old Colles' fracture (see Fig. 1446).

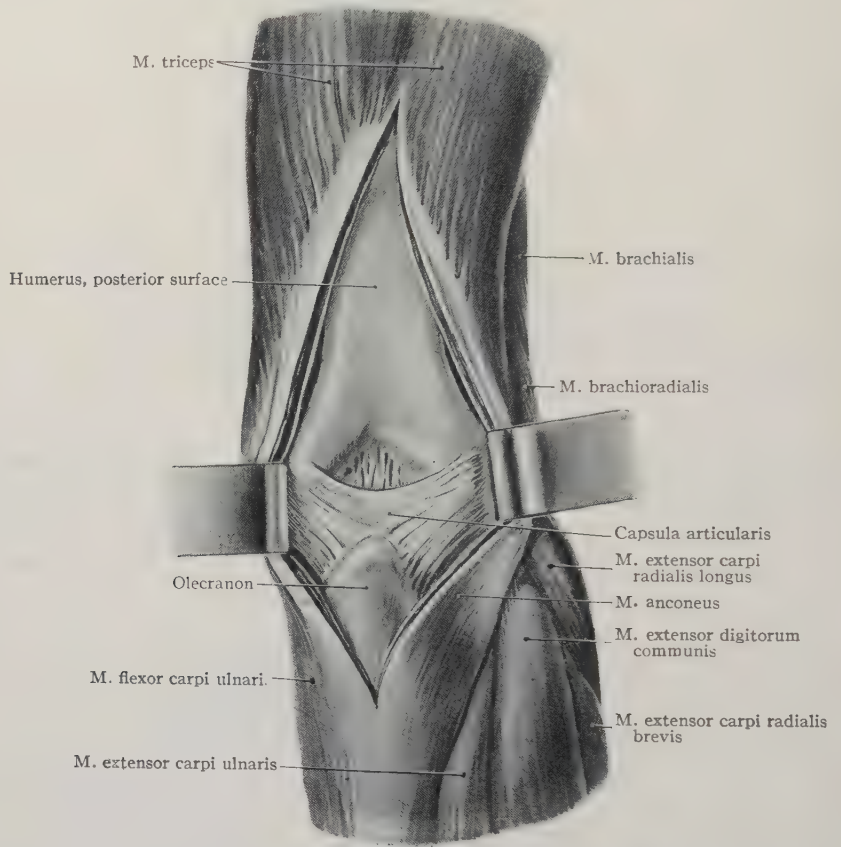


Fig. 1438.—The posterior approach to the region of the elbow by a longitudinal median incision. Note the olecranon and the posterior surface of the lower end of the humerus.

The *upper end of the radius* may be reached safely through a long vertical incision from the external condyle downward, separating the bellies of the extensor communis digitorum and extensor carpi radialis brevis. Retract the communis medially a slight distance. Retract the extensor brevis laterally (see Fig. 1432). The interval between these muscles can be found easily at the middle of the forearm. It is difficult to find high up. This separation exposes the supinator with the radius beneath as well as both above and below the attachment of the supinator.

The Middle of the Radius.—By an incision which retracts posteriorly the extensor carpi radialis longus and brevis, and which retracts the brachioradialis forward the portion of the shaft of the radius which lies between the insertion of the supinator brevis and the origin of the abductor pollicis longus is exposed (Fig. 1439). And this exposure may be continued down to include the lower third of the radial shaft. The insertion of the pronator radii teres will be seen at the middle of the shaft of the bone.

Head and Neck of the Radius.—The brachioradialis muscle, together with the aponeurosis of the extensor communis digitorum and the extensor carpi radialis longus, cover the head and neck of the radius. By splitting the at-

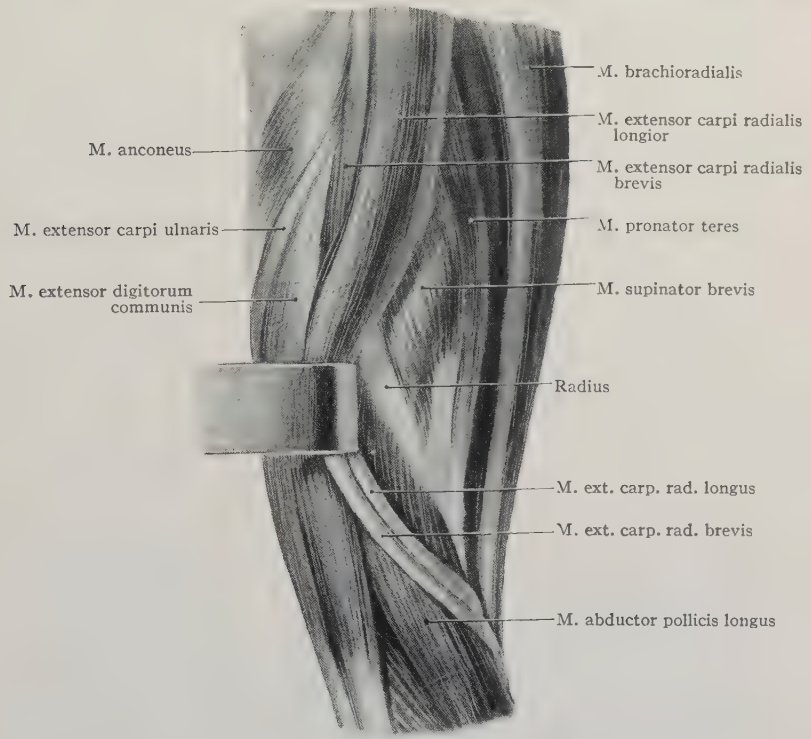


Fig. 1439.—Note approach to the shaft of the radius by retraction posteriorly of the extensor carpi radialis longus and brevis. Note the supinator brevis and the pronator radii teres.

tachment of the extensor communis digitorum the head of the radius is exposed, lying under the annular ligament. The posterior interosseous nerve winding to the back of the forearm around the outer side of the radius, passes obliquely between the fibers of the supinator brevis (Fig. 1442).

The *radial nerve* (musculospiral) gives branches to the brachioradialis and to the extensor carpi radialis longus near their origins, as it lies between them and the brachialis muscle in front of the lower end of the humerus.

In the hollow of the elbow, in front of the lateral epicondyle, it divides into the cutaneous (radial nerve) superficial ramus and the muscular (posterior interosseous nerve) deep ramus.

The deep ramus passes distally and posteriorly. It gives off immediately branches to the extensor carpi radialis brevis and to the supinator.

It then penetrates the substance of the supinator on its lateral aspect, just below the level of the head of the radius and lies embedded in the muscular fibers almost as far as its lower border, where it emerges under cover of the extensor digitorum communis to which it gives branches at once.

Retraction of the extensor communis digitorum is resisted opposite the lower border of the supinator, because both the nerves and arteries enter the muscle at this point. This is the danger zone.

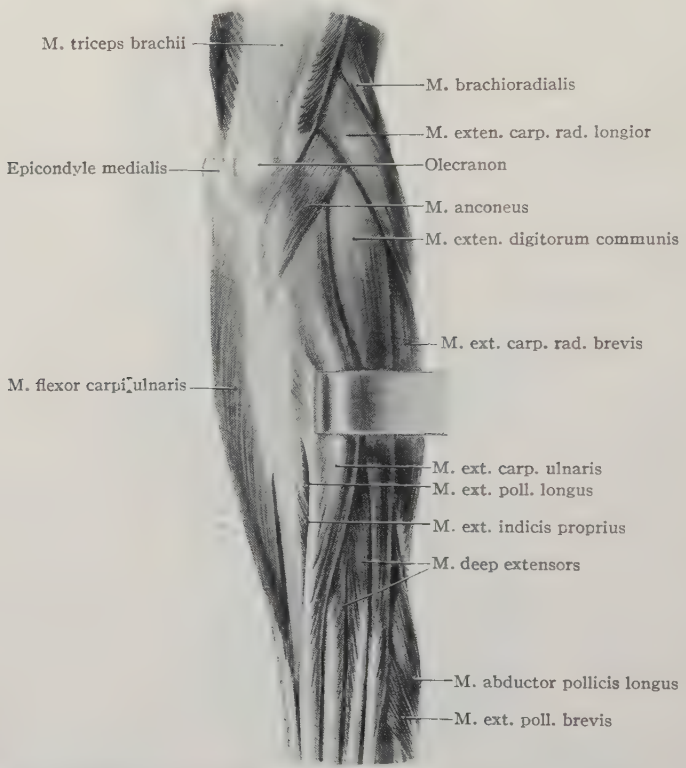


Fig. 1440.—Note the approach to the ulnar shaft between the flexor and extensor carpi ulnaris muscles.

The part of the nerve lying within the supinator passes obliquely along. It lies 2 cm. below the joint line on the lateral aspect of the radius and about 5 cm. below the joint line on its posterior aspect.

In actual operative work on the area of bone covered by the supinator it is wise (Thompson) to peel the muscle from the bone and retract it. Traction should be made gently when retracting this muscle.

The ulna is subcutaneous on its posterior lateral border throughout its entire length. It is, therefore, readily accessible (Figs. 1440, 1441). The subcutaneous border of the ulna lies between the flexor carpi ulnaris and the

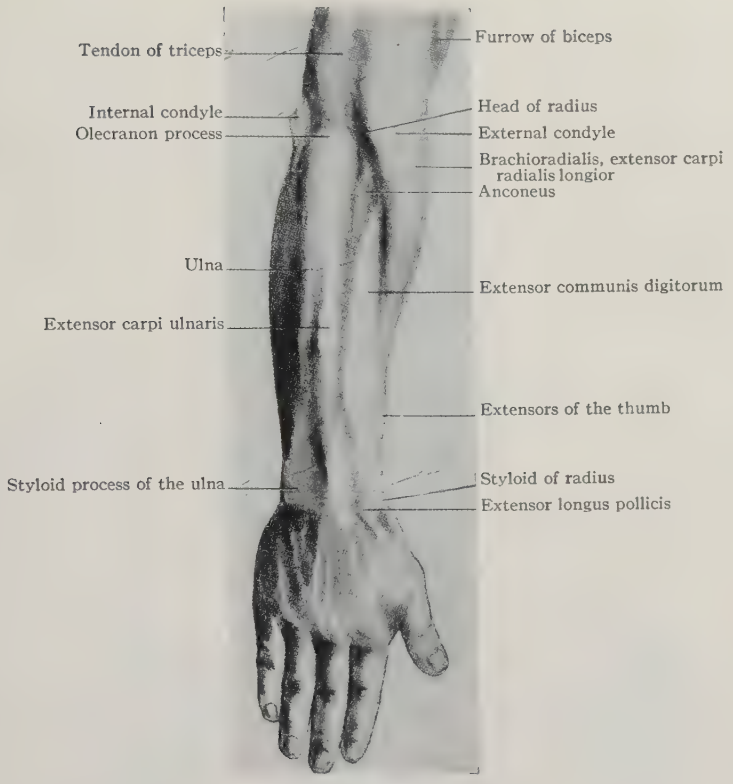


Fig. 1441.—Posterior surface of the forearm, wrist, and hand. This is often a desirable prone position in operations on the forearm (after Davis).

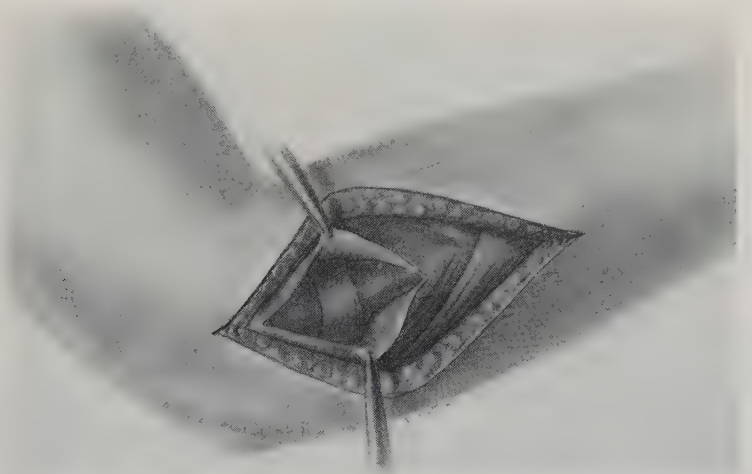


Fig. 1442.—The fibers of the brachioradialis and extensor carpi radialis longior are retracted laterally, illustrating the approach to the radiohumeral articulation in the operation of removal of the fractured head or neck of the radius. Note through the fibers of the supinator brevis muscle the posterior interosseous nerve lying like a white line in the upper right side of the drawing. This nerve is to be carefully avoided when operating.

extensor carpi ulnaris (see Fig. 1440). The approaches to fractures of both the radius and ulna should ordinarily be posteriorly rather than anteriorly.

The Olecranon Process of the Ulna.—In operations on fracture of the olecranon great care must be taken not to injure the ulnar nerve. The nerve passes distally between the two heads of the flexor carpi ulnaris and lies on the inner aspect of the base of the olecranon. It is ordinarily wise to expose carefully the nerve so that it may be seen and adequately cared for while operative procedures in its immediate vicinity are in progress, particularly if the operation is extensive.

Fig. 1443.—Fracture of both bones of the forearm. Illustrating incision on radial side of forearm. Same as Fig. 1444. The prone position of the patient is a convenient position for operating, as the incision is placed dorsally.

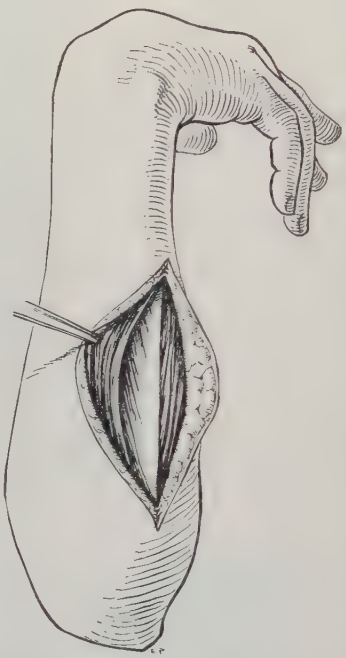


Fig. 1444.—Illustrating incision on the ulnar side of the forearm in case of fracture of both bones of the forearm with forearm held at a right angle with arm or with patient prone on operating table.

Anatomical Facts.—By consulting the points of origin and attachment of the muscles to the radius and ulna much valuable information as to appropriate and safe approaches to the bone will be obtained (see Fig. 1422). The proximal two-thirds of the radius on its anterior part is rather deeply placed beneath muscle bellies. The necessity for accurate knowledge of muscular planes is evident.

The radial (musculospiral) nerve pierces the lateral intermuscular septum at the junction of the proximal and middle third of a line extending from the insertion of the deltoid to the lateral epicondyle, where the nerve divides into its deep and superficial branches.

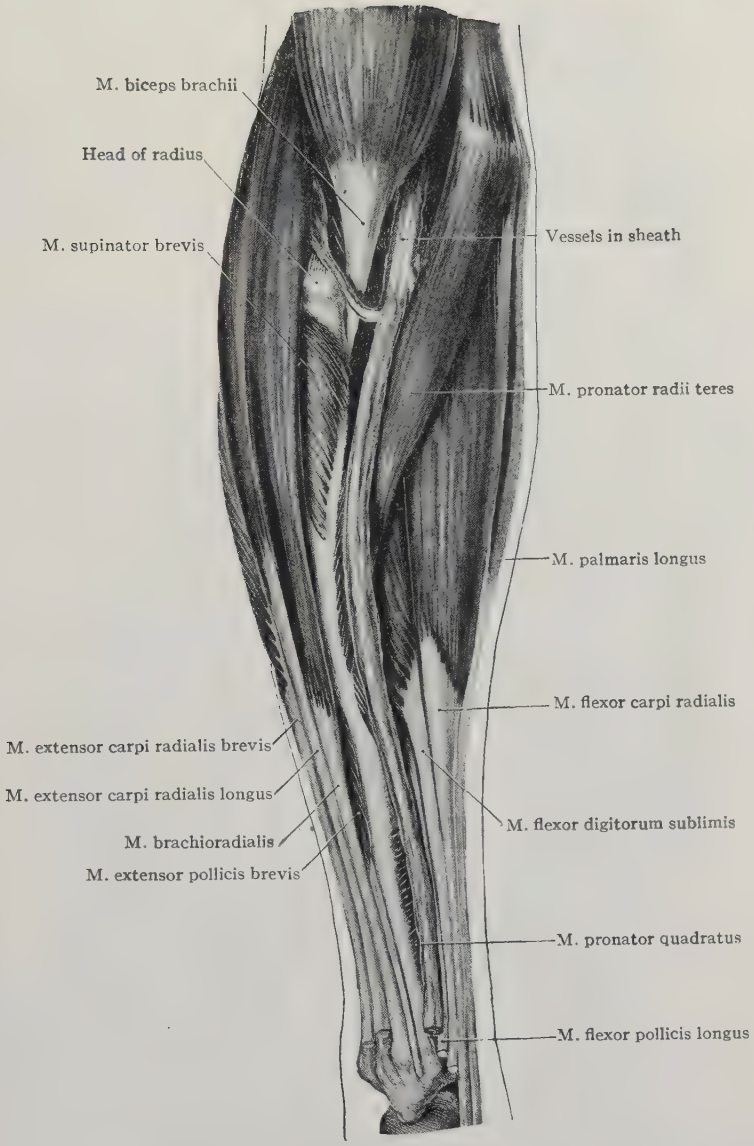


Fig. 1442*a*.—Exposure of radial shaft by anterolateral incision. (After Henry, Dublin, British Journal of Surgery, January, 1926.)

Complete Exposure of the Radius by An Anterolateral Incision.[1]—The elbow is extended, the hand is supinated. The incision, extending from a little above the bend of the elbow to the tip of the radial styloid process, exposes the outer edge of the biceps belly and its tendon of insertion. A recurrent vascular loop is tied and divided between ligatures. The three long muscles are retracted outward, returning to the biceps tendon at its outer side, the knife is entered close to the tendon's outer side and the cut

[1] Arnold K. Henry, Dublin, British Journal of Surgery, January, 1926.

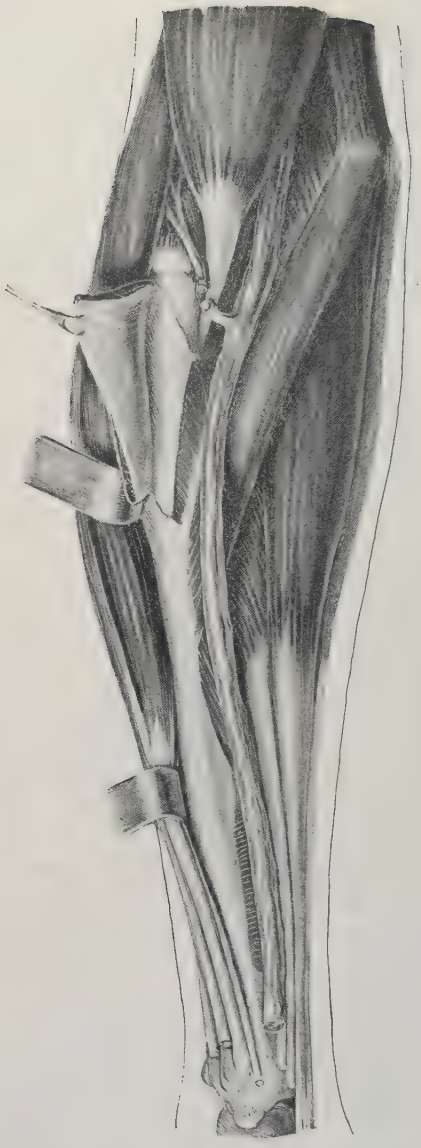


Fig. 1442*b*.—Exposure of radial shaft. Second step. (After Henry, Dublin, British Journal of Surgery, January, 1926.)

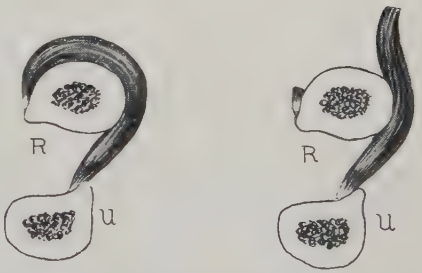


Fig. 1442*c*.—Exposure of radial shaft. Division of supinator brevis at its attachment to the radius: R, Radius; U, ulna. (After Henry, Dublin, British Journal of Surgery, January, 1926.)

is carried down directly to the radial tuberosity. The supinator brevis attachment is elevated, and the muscle is turned outward, carrying with it the posterior interosseous nerve. The radius by being pronated is exposed from one end to the other.

Obviously, any portion of this incision may be employed to expose certain parts of the radial shaft according to the exigencies of the case in hand.

The course of the radial (musculospiral) nerve is along a line obliquely drawn distally and forward from this point of perforation of the septum to the point of the lateral epicondyle.

Where the nerve lies in the radial groove on the humerus may be determined by drawing a line from the same perforating septum point obliquely proximally across the prominence of the lateral head of the triceps to the junction of the posterior fold of the axilla with the arm.

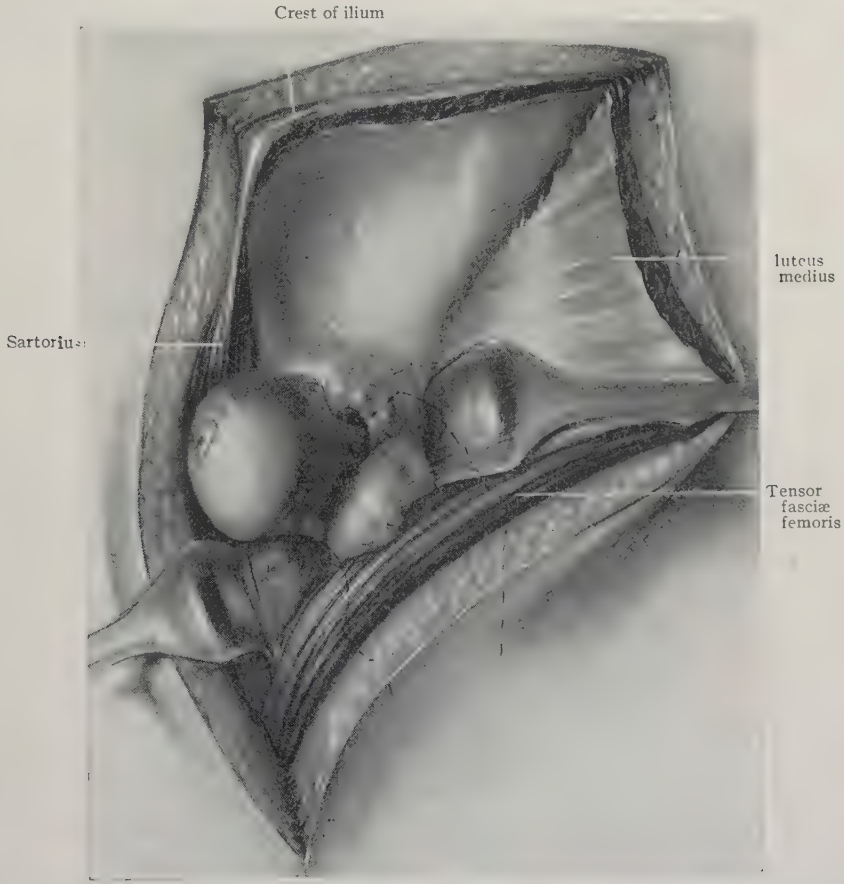


Fig. 1445.—Smith-Petersen approach to the hip-joint. Note outer side of ilium with reflected muscle. Capsule opened, head extruded.

Operations on the Carpus.—The dorsal approach by longitudinal incision over the bone involved is the one of choice (see Fig. 1447). Operations on the scaphoid bone are easily reached by this approach. A palmar approach by median incision avoiding all tendons and nerves affords ample access to the semilunar bone or the scaphoid bone (see Fig. 1448).

The Femur.—*Smith-Petersen Supra-articular Subperiosteal Approach to the Hip-joint* (Fig. 1445).—The individual steps of the operation are as follows:

1. Anterior incision. Incision from the anterosuperior spine along the anterior border of the tensor fascia femoris, to below the level of the trochanter. This incision follows an intermuscular plane between the sartorius anteriorly, and the tensor fascia femoris posteriorly; the only structure divided is the fascia femoris, and this is split along the course of its fibers.

2. Curved incision. Incision from the anterosuperior spine along the crest of the ilium.

3. Subperiosteal dissection: The flap outlined by these two incisions is freed from the ilium by subperiosteal dissection; the extent to which the flap is reflected posteriorly depends upon the demands of the individual

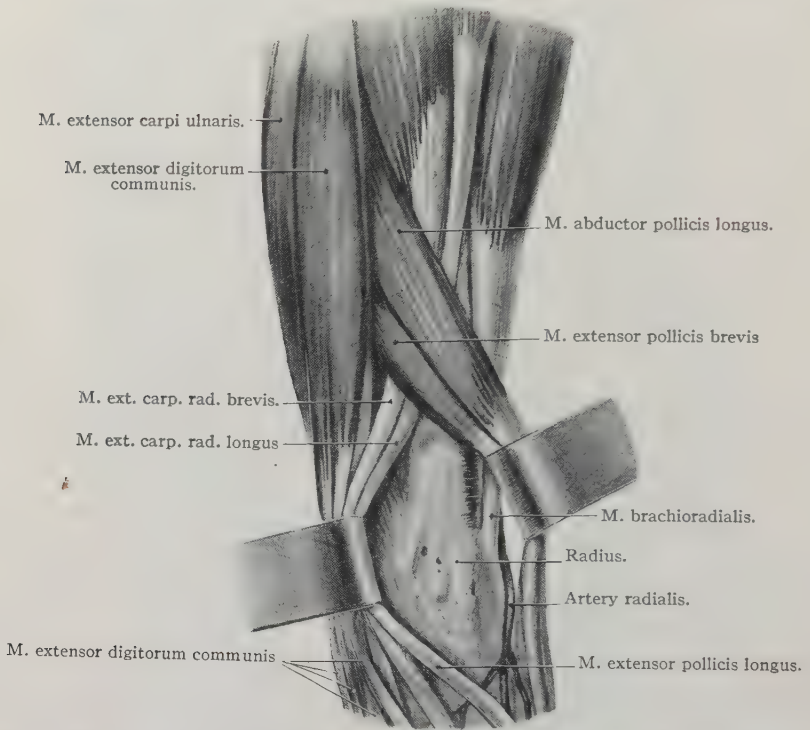


Fig. 1446.—Note the anatomy of this radial side of the lower forearm and wrist. By *moderate* retraction the styloid process and outer side of the lower end of the radius is beautifully accessible.

operation. By reflecting the origin of the tensor fascia femoris with the flap, the superior gluteal nerve and artery are preserved.

4. Incision of capsule: The chief point to keep in mind is the preservation of the Y-ligament of Bigelow. The incision is, therefore, made in the superior portion of the capsule, just above the border of this structure. The capsule is freed posteriorly along the cotyloid ligament so as to give the desired exposure (see Fig. 1445).

The femoral shaft is ordinarily approached from the outer side by a long external incision. This involves splitting and cutting fibers of the vastus externus and crureus (see Fig. 1459). This approach is safe from

large vessels, but the small vessels are quite numerous and several will have to be ligated. The method planned by Henry and used successfully is the one now described. It is an almost bloodless method.

Operation: Approach to the Shaft of the Femur.—The skin and deep fascia are divided along a line from the anterosuperior iliac spine to the outer angle of the patella (see Fig. 1450). The interval between the rectus femoris and vastus externus is found about a handbreadth below the great trochanter. The muscles are separated, one or two vessels are divided in this maneuver. In the lower third of the thigh the aponeurotic fibers of the vastus join the rectus tendon and the knife must be used to separate them. When these

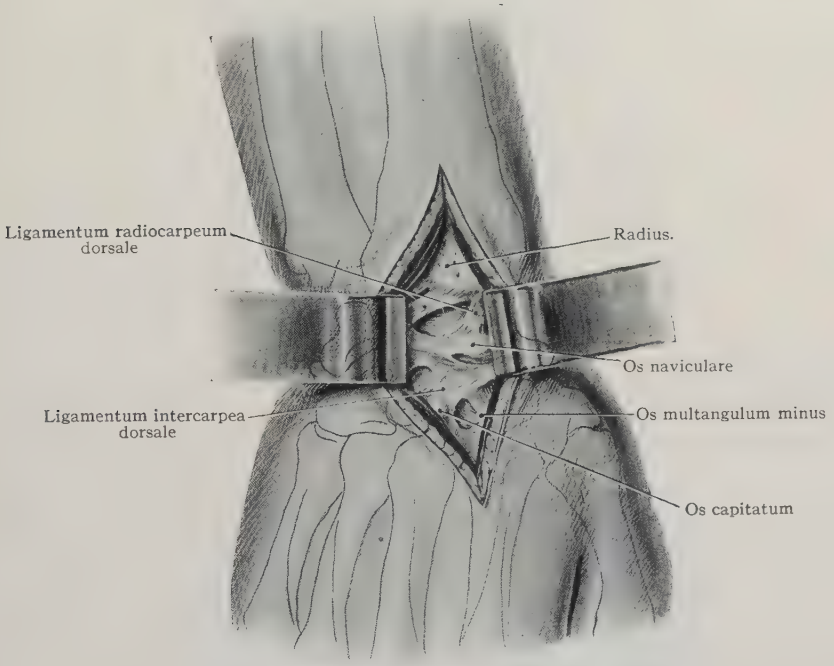


Fig. 1447.—Note posterior longitudinal incision at middle of radius over the wrist-joint and navicular (scaphoid) bone. All extensor tendons and their sheaths have been carefully retracted. Note the dorsal ligaments of the carpus exposed.

muscles are held apart the silvery surface of the crureus (vastus intermedius) is exposed (see Fig. 1451). The oblique descending branches of the external circumflex vessels and the nerve to the vastus externus are now seen passing across the crureus from beneath the rectus femoris to enter the free edge of the vastus externus into which they disappear. They are all retracted proximally upward (see Fig. 1452). By dividing the crureus in its upper part to the bone the shaft of the femur is exposed (see Fig. 1452). The suprapatellar pouch which lies as high as a handbreadth above the upper patella border is avoided by stopping the incision in the crureus above this point. The pouch may be separated from the femur by periosteal elevator. It is unwise to attempt to separate the pouch from the quadriceps, as it will

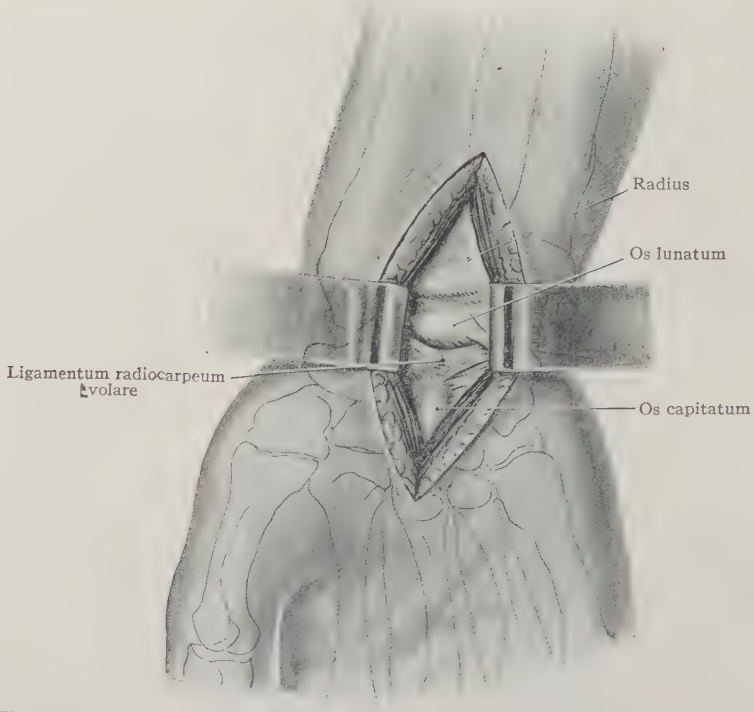


Fig. 1448.—Note anterior longitudinal incision at the middle of the wrist exposing deeply, after retraction of the tendons and nerves, the anterior carpal ligaments, and the region of the os lunatum (semilunar bone). On the radial side of the anterior surface of the wrist directly in line with the tendon of the flexor carpi radialis is the prominent tubercle of the navicular or scaphoid bone.

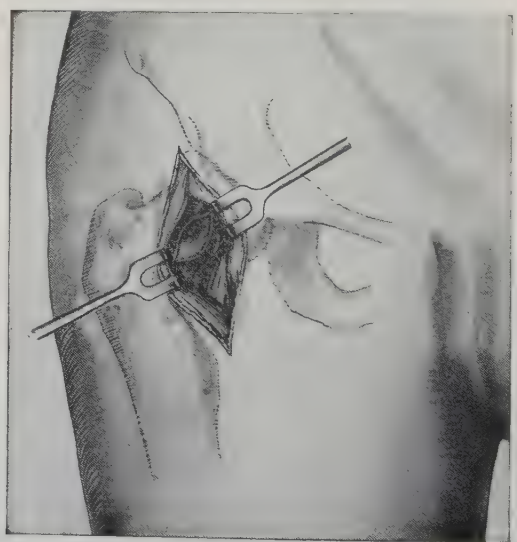


Fig. 1449.—Arthrotomy of the hip by an anterior incision to the outer side of the sartorius. The inner retractor is displacing the sartorius inward, beneath which the rectus muscle is seen. The outer retractor is displacing the tensor fasciæ lateralis outward. At the bottom of the retracted wound the capsule is seen split axially over the neck of the femur (Bickham, Operative Surgery, vol. ii).

be lacerated. The greater part of the femoral shaft is exposed by this approach. The attachment of muscles to the linea aspera may be seen.

Approach to the Distal Extremity of the Femur (Thompson).—By this is meant the epicondyles and condyles (see Fig. 294). The anterior, posterior, and inferior surfaces of the medial and lateral condyles are covered with cartilage and lie inside the capsule of the knee-joint (see Fig. 295) The anterior and posterior crucial ligaments are attached to the intercondyloid fossa, which is a deep space lying between the condyles

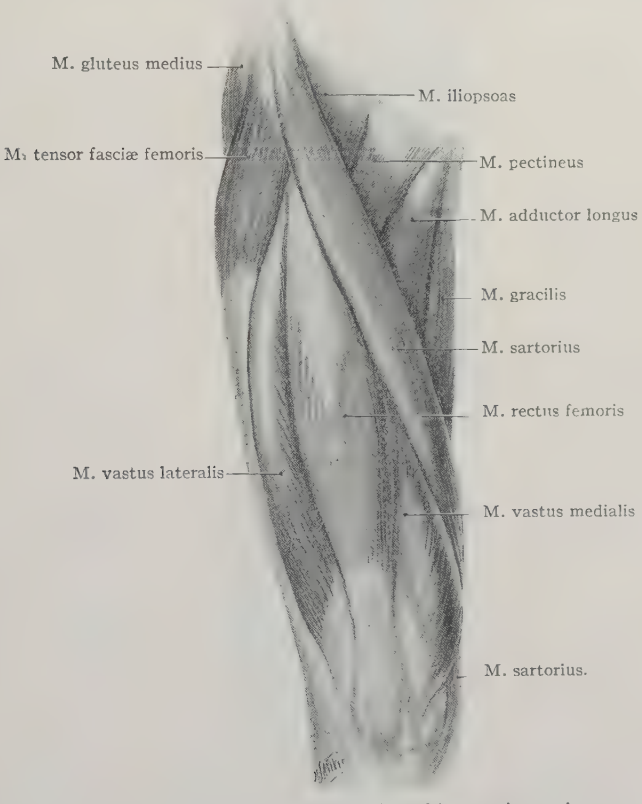


Fig. 1450.—Note the musculature of the anterior hip, thigh, and knee regions. An easy access to the femur is suggested. See text.

posteriorly. The patella lies in the groove between the condyles in front. It would be impossible to expose the bone from in front or behind without opening the joint cavity. The lateral aspect of each condyle is subcutaneous and on each there is a projection called the epicondyle. The medial epicondyle projects very prominently. It is capped by the adductor tubercle and to it are attached the fibers of the tibial lateral ligament of the knee-joint. It corresponds to the epiphyseal line. The lateral epicondyle is not so prominent. Just distal to its most prominent part the popliteus tendon lies in its bony groove; while just posterior to it is attached the fibular lateral ligament. The synovial membrane is attached to the femur all around

the line of junction of bone and cartilage. The actual joint cavity, however, overlaps the lateral and anterior aspects of the bone to a large extent and makes it necessary for us to plan an incision *outside the line of reflexion* of the synovial membrane so as to peel it from its recesses and to uncover the bone. The lower surface of the shaft in front is covered by the upper part of the synovial cavity for quite a distance above the level of the upper border of the patella, but the synovial membrane can be peeled from this surface as low down as the cartilaginous margin without opening the joint cavity.

Fig. 1451.—The anterior and lateral approach to the shaft of the femur between the vastus lateralis and the rectus. Note the vastus intermedius lying on the anterior surface of the femur. Note the descending branch of the external circumflex artery and vein and nerve to the vastus lateralis (externus) (after Henry, Dublin).

Similarly on the lateral aspects of the condyle an area in front of each epicondyle is overlapped by the lateral recesses of the joint cavity. The drawings in Fig. 296 representing the lateral and medial aspects of the condyles show by dotted lines the actual line of attachment of the synovial membrane and its line of reflexion. The line of attachment is shown by the dotted line *b*; that of reflexion by the dotted line *a*. The line *c* represents the fusion of *a* and *b* (Thompson).

The area proximal to and behind the dotted line, showing the line of reflexion of the synovial membrane, is absolutely safe for surgical approach.

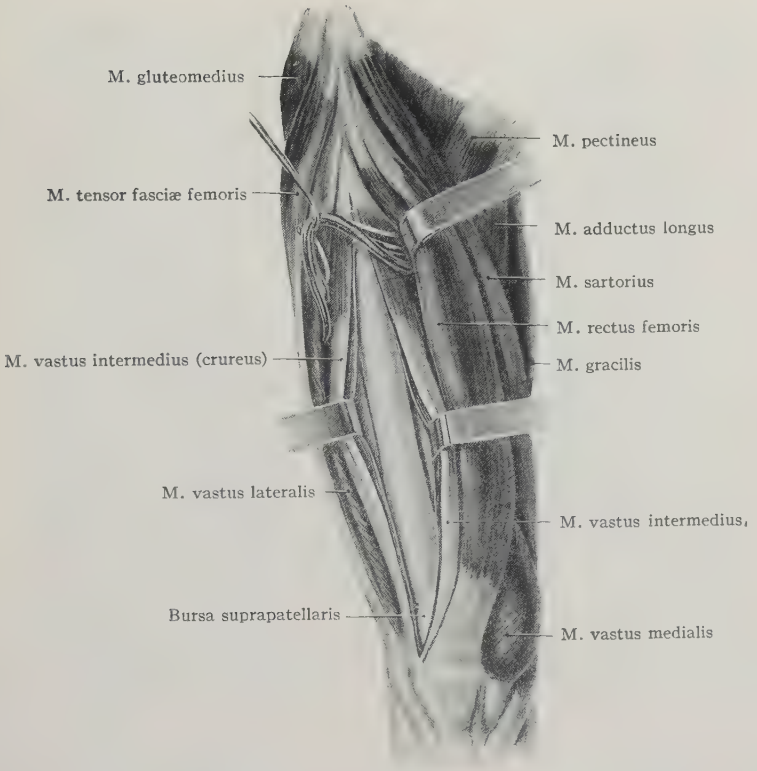


Fig. 1452.—The anterior and lateral approach to the shaft of the femur. Note that the neurovascular bundle is retracted upward and that the vastus intermedius (crureus) is split along its center anteriorly, giving access to the femoral shaft. The suprapatellar pouch is to be avoided by stopping the incision a handbreadth proximal to the pointed end of the patella (after Henry, Dublin).

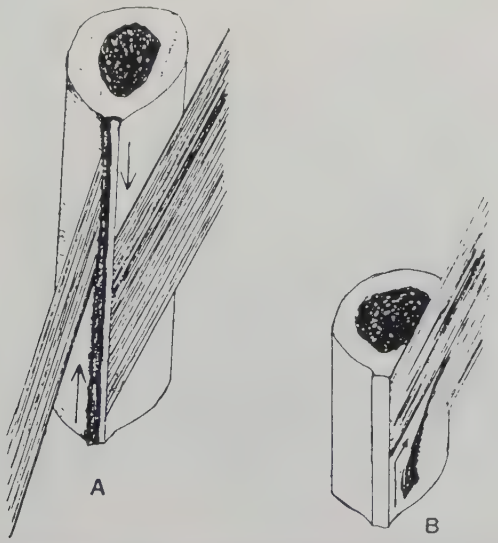


Fig. 1453.—Work the periosteal elevator into the acute angle A which the muscular attachments make with the bone. B shows how rugine tears into a muscle when used in the reverse direction against the obtuse angle (A. K. Henry, Dublin, British Journal of Surgery, xii, 1924).

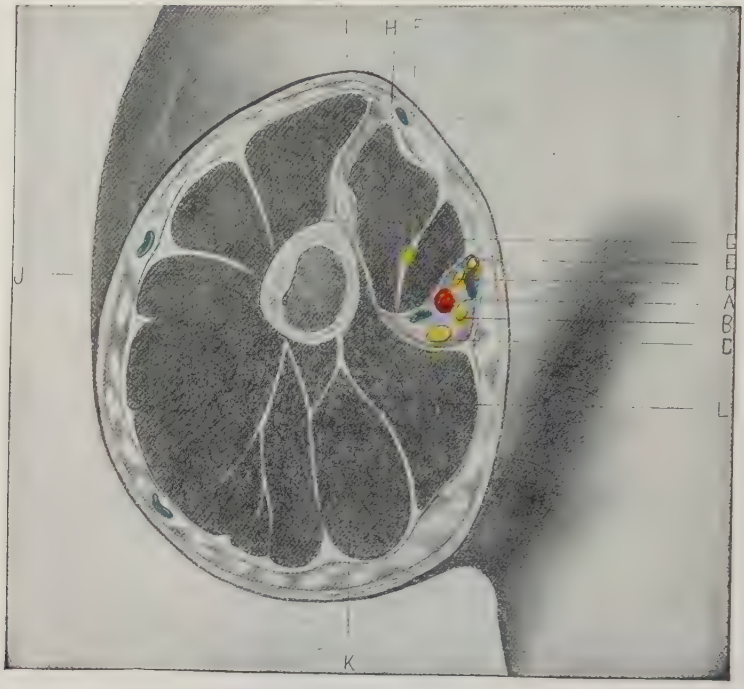


Fig. 1454.—Cross-section of the right arm at the axillary level: A, Axillary artery and vein; B, ulnar nerve; C, muscolospiral nerve; D, median nerve; E, internal cutaneous nerve; F, musculocutaneous nerve; G, coracobrachialis muscle; H, biceps; I, pectoralis major muscle and biceps tendon; J, deltoid; K, triceps; L, latissimus dorsi. (The cross-section modified from Esmarch.) (From Bickham, Operative Surgery, vol. i.)

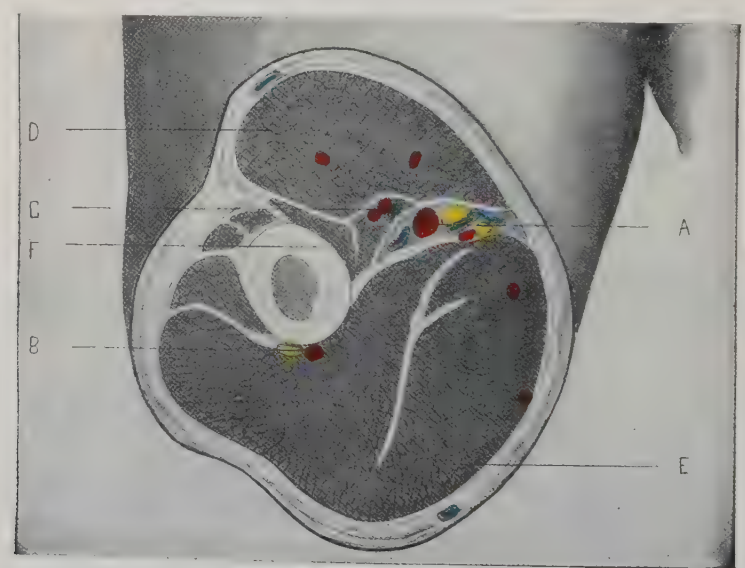


Fig. 1455.—Cross-section of the middle of the right arm: A, Brachial artery and veins and inferior profunda artery and median and ulnar nerves; B, musculospiral nerve and superior profunda artery; C, nutrient vessels; D, biceps muscle; E, triceps; F, brachialis anticus muscle (Cross-section modified from Braune.) (From Bickham, Operative Surgery, vol. ii.)

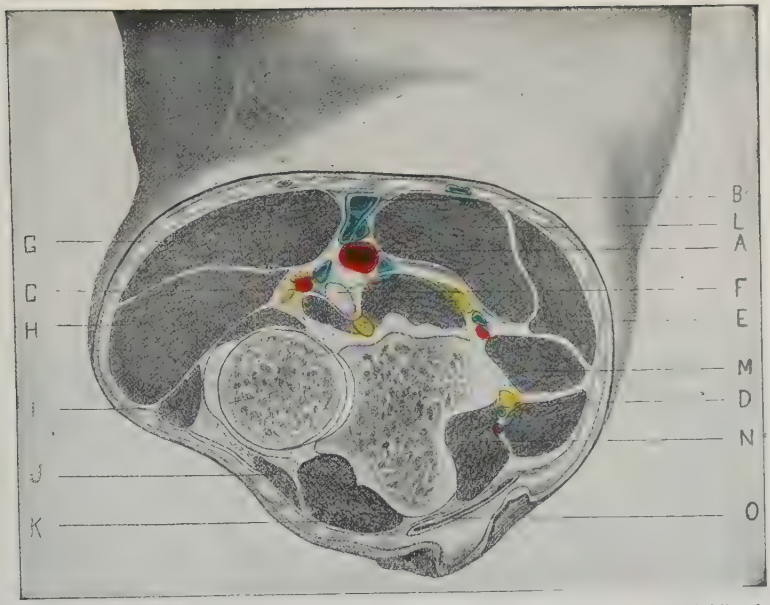


Fig. 1456.—Cross-section of right arm just below the elbow-joint: A, Brachial artery dividing into radial and ulnar, with venæ comites; B, median basilic vein; C, radial recurrent artery and radial and interosseous nerves; D, ulnar nerve and posterior ulnar recurrent artery; E, median nerve and anterior ulnar recurrent artery; F, biceps tendon; G, supinator longus muscle; H, extensor carpi radialis longior; I, extensor carpi radialis brevior; J, extensor carpi ulnaris; K, anconeus; L, pronator radii teres; M, flexor sublimis digitorum; N, flexor carpi ulnaris (a fascial line is seen between its two parts). The brachialis anticus muscle lies just below the brachial artery. The flexor carpi radialis lies just to the right of the pronator radii teres. (The cross-section modified from Braune.) (From Bickham, Operative Surgery, vol. ii.)

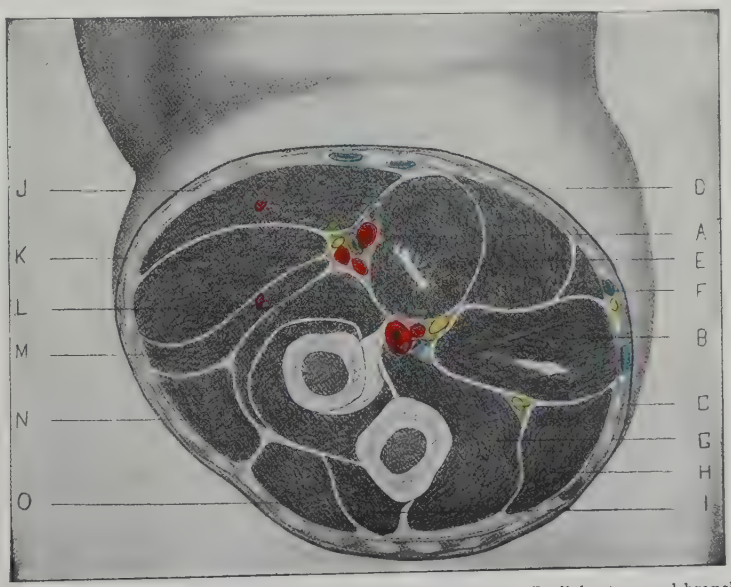


Fig. 1457.—Cross-section of the upper third of the right forearm: A, Radial artery and branches, veins, and nerve; B, ulnar and interosseous arteries, veins, and median nerve; C, ulnar nerve; D, pronator radii teres muscle; E, flexor carpi radialis; F, subcutaneous vein and nerve; G, flexor profundus digitorum; H, flexor carpi ulnaris; I, anconeus; J, supinator longus; K, extensor carpi radialis longior; L, supinator brevis; M, extensor carpi radialis brevior; N, extensor communis digitorum; O, extensor carpi ulnaris. (Cross-section modified from Braune.) (From Bickham, Operative Surgery, vol. ii.)

It will be seen that both lateral and medial epicondyles (shown by a cross) are outside this area, and that there is a considerable area of bone above and behind these prominences, directly accessible. A vertical incision extending proximally from the epicondyles could be carried down to bone without risk of opening the knee-joint. On the medial side, it would cut through the aponeurotic expansion passing from the vastus medialis to the side of the patella and at a higher level the vastus medialis muscle itself. On the lateral aspect it would split the iliotibial band of fascia lata tractus iliotibialis and also at a much higher level sever the fibers of the vastus lateralis. By peeling the deeper structures from the bone backward and forward a large

Fig. 1458.—Cross-section of the left thigh, through the head of the femur (the skin relations of this section erroneously represent a lower level): A, Iliacus; B, sartorius; C, femoral artery, vein, and crural nerve; D, pectineus; E, psoas; F, tensor vaginæ femoris; G, gluteus minimus; H, gluteus medius; I, great sciatic artery, vein, and nerve; J, gluteus maximus; K, obturator internus; L, obturator externus; M, adductor brevis; N, adductor longus. (The cross-section from Braune.) (From Bickham, Operative Surgery, vol. ii.)

area could be exposed for operative procedures. In front the reflexion of synovial membrane would be brushed away and there would be no danger of opening the articulation. In fractures through the condyles and T-fractures, nails or screws can be inserted in this area (Thompson).

Separation of the Muscles from the Linea Aspera.—The ease of separating the muscles from the linea aspera will depend on whether the periosteum elevator is worked into the acute angle of the muscle attachments or not (Fig. 1453). The adductors extend down *to* the femur, while the vasti and short head of the biceps extend *from* the femur. These various attachments are cleanly separated by proceeding with the method indicated in legend of Fig 1453.

The Tibia and Fibula.—These bones, being fixed (unlike the radius and ulna) and essentially subcutaneous, are easy of access at any part of their extent. In the upper fourth of the tibia the tendons of the sartorius, gracilis and semitendinosus overlap the bone. The line of approach to the tibia is along the line of its subcutaneous surface from the medial tuberosity proximally to the tip of the medial malleolus distally. The approach to the fibula in its lower fourth is along the line of its subcutaneous surface. The proximal four-fifths of the fibula is covered by muscles. Separation of the peronei

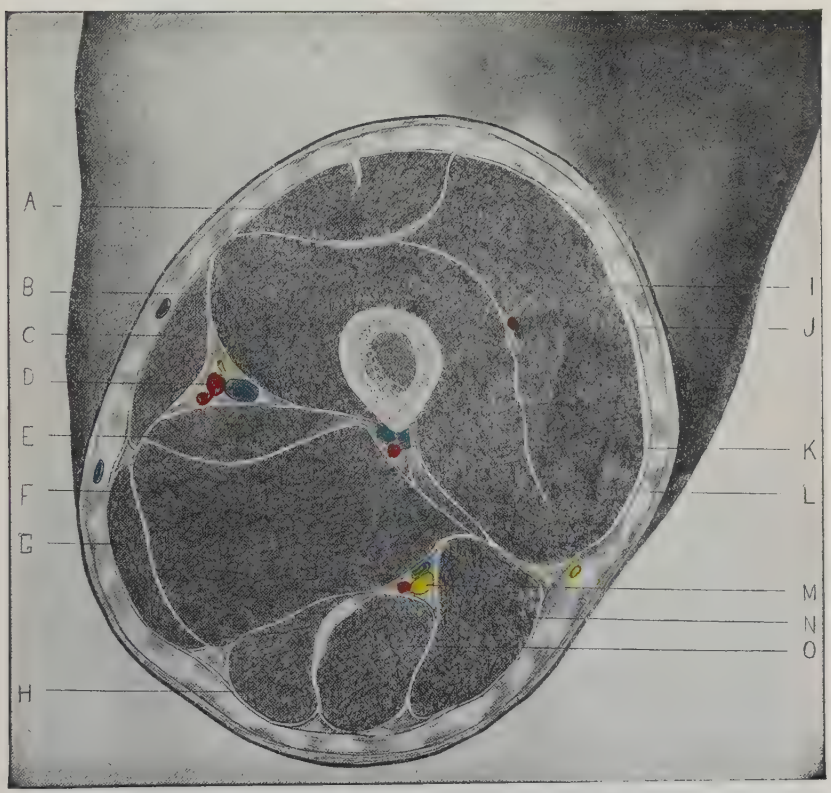


Fig. 1459.—Cross-section through the middle of the left thigh: A, Rectus muscle; B, vastus internus; C, sartorius; D, superficial femoral artery, vein, and saphenous nerve; E, adductor longus; F, adductor magnus; G, gracilis; H, semimembranosus; I, vastus externus; J, descending branch of external circumflex; K, terminal branch of profunda femoris; L, crureus; M, great sciatic nerve and arteria comes nervi ischiadici; N, biceps; O, semitendinosus. (The cross-section modified from Braune.) (From Bickham, Operative Surgery, vol. ii.)

from the calf muscles is the safest approach to the fibula in its upper four-fifths.

At the upper end of the shaft about one inch below the fibula head lies the deep peroneal nerve, winding around the outer surface of the shaft in the substance of the peroneus longus muscle.

In the upper third of the shaft the dissection passes between the peroneus longus and the soleus. In the middle third of the shaft the dissection passes between the peroneus longus and the flexor hallucis longus.

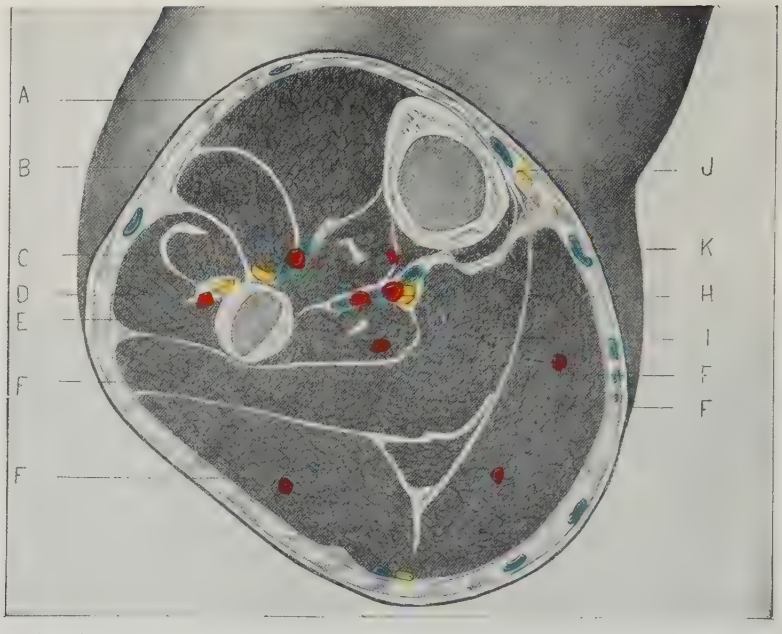


Fig. 1460.—Cross-section through the upper third of the right leg: A, Tibialis anticus; B, extensor longus digitorum; C, anterior tibial vessels and nerve; D, musculocutaneous nerve; E, peroneus longus; F, F, F, F, gastrocnemius; H, posterior tibial vessels and nerve; I, soleus; J, internal saphenous vein and nerve; K, popliteus. (The cross-section modified from Braune.) (From Bickham, Operative Surgery, vol. ii.)

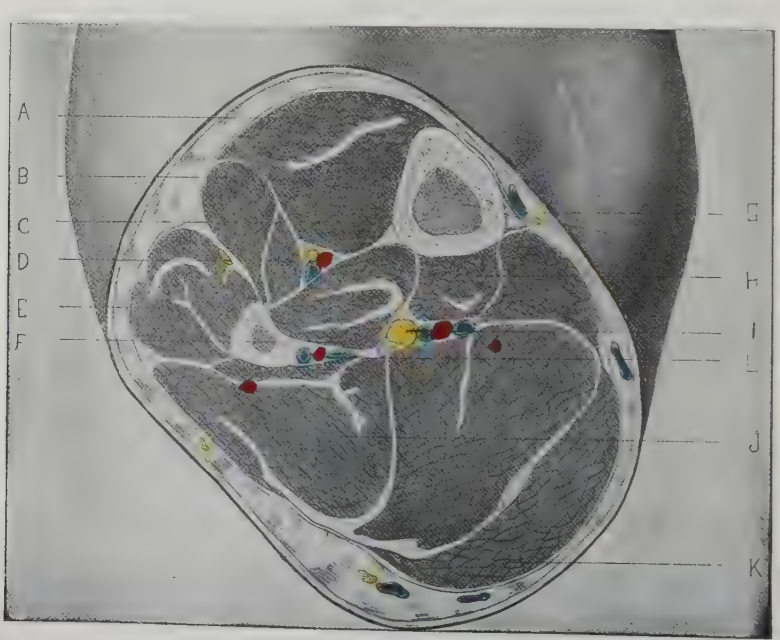


Fig. 1461.—Cross-section of the middle of the right leg: A, Tibialis anticus; B, extensor longus digitorum; C, extensor pollicis; D, anterior tibial artery, vein, and nerve; E, peronei; F, tibialis posticus; G, long saphenous vein and nerve; H, flexor longus digitorum; I, posterior tibial artery, veins, and nerve; J, soleus; K, gastrocnemius; L, peroneal artery and veins. (The cross-section modified from Braune.) (From Bickham, Operative Surgery, vol. ii.)

CHAPTER XXV

SPECIAL OPERATIONS

Fracture of the mandible, bone plastic—Shaft of the humerus, apparatus after operation—Fractures at the elbow—Fracture of the olecranon—Colles' fracture, lesion associated with; old fracture—Ununited fracture of the neck of the femur: Cotton impaction: Brackett operation: Whitman operation: Bone pegging the neck of the femur—Fracture of the shaft of the femur: Sherman clinic, postoperative course—Magnuson clinic, postoperative case—Operations for fracture of the patella—The Freeman Bone-clamp—Old Pott's fracture.

In this chapter are grouped certain fractures requiring particular mention. It is recognized that any fracture may need operative treatment under peculiar conditions. Compound or open fractures, ununited fractures, old deformed fractures with disabling symptoms will always require operation.

FRACTURE OF THE MANDIBLE. CONDUCT OF BONE PLASTIC ON THE MANDIBLE, ILLUSTRATED

Cole has clearly described and illustrated the steps followed by him in grafting a fracture of the mandible with some loss of substance. He has taken

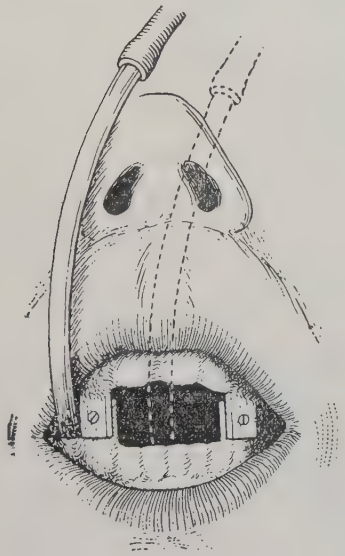


Fig. 1462.—Anesthesia through pharyngeal tubes.

Fig. 1463.—Operative field securely protected by sterile towels

(P. P. Cole, British Journal of Surgery, vol. 6, p. 67.)

the graft from the tibia or from the rib or has employed a pedicled graft from the mandible itself. Consult the accompanying illustrations for the essential operative details of Cole's methods.

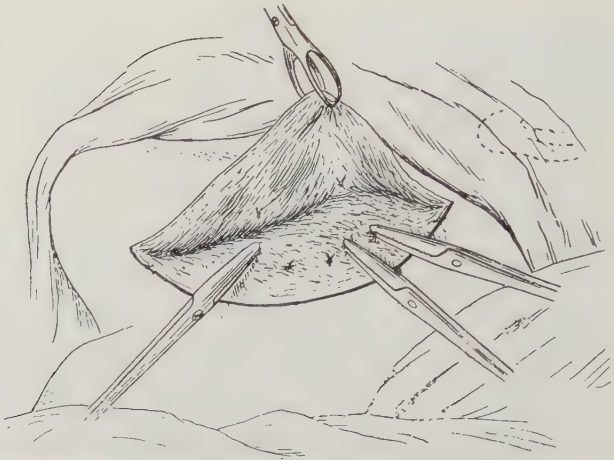


Fig. 1464.—Curved incision under chin to expose the seat of fracture (P. P. Cole, British Journal of Surgery)

Fig. 1465.—Each fragment is exposed, cleaned, freshened, and shaped satisfactorily (P. P. Cole. British Journal of Surgery).

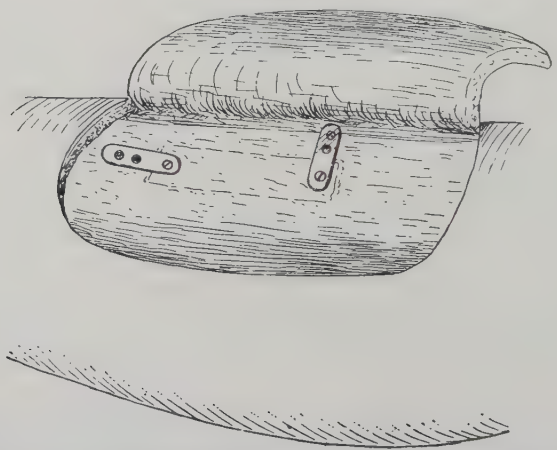


Fig. 1466.—Removal of graft from tibia of patient. Size and site of graft outlined by knife. The small plates screwed to the graft before the detaching cross-cuts are made (P. P. Cole, British Journal of Surgery).

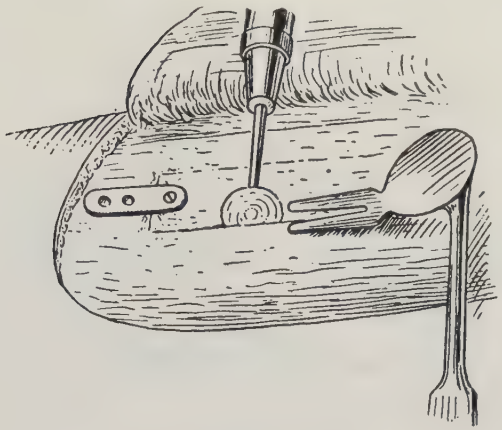


Fig. 1467.—Securing the tibial graft. Circular saw cutting longitudinally. Protecting guide used (P. P. Cole British Journal of Surgery).

Fig. 1468.—The wound in the skin has been closed and a drainage-tube left *in situ* temporarily for twenty-four hours (P. P. Cole, British Journal of Surgery).

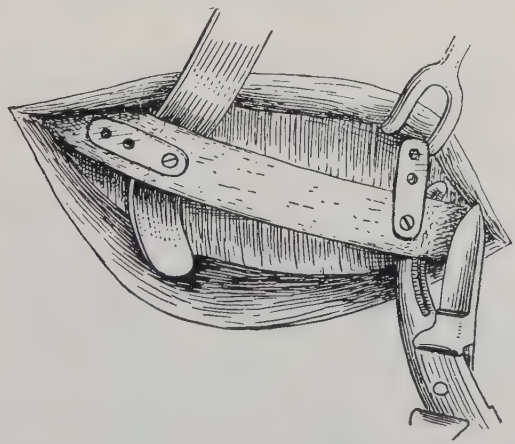


Fig. 1469.—Removal of the rib graft. Screws fixed in graft *before* removal of rib (P. P. Cole, British Journal of Surgery).

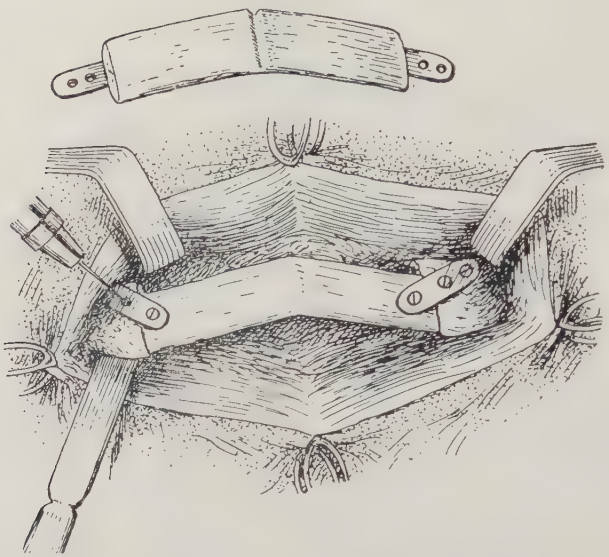


Fig. 1470.—The same technic in taking a rib graft is used as is used in taking graft from the tibia. The rib graft is introduced and fastened by small screws (P. P. Cole, British Journal of Surgery).

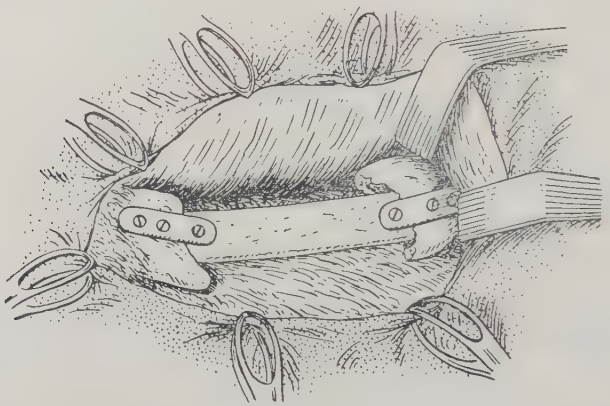


Fig. 1471.—The graft is fixed in the gap between maxillary fragments by two screws attaching each plate to the corresponding fragment of the fracture (P. P. Cole, British Journal of Surgery).

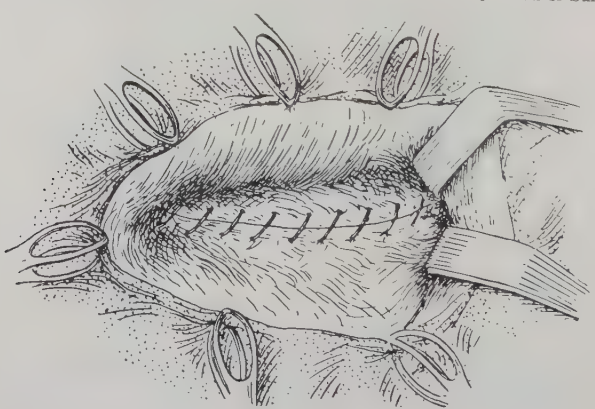


Fig. 1472.—The wound is closed (P. P. Cole, British Journal of Surgery).

Fig. 1473.—Fracture of the inferior maxilla. Cutting a pedicled flap from the anterior fragment (P. P. Cole, British Journal of Surgery).

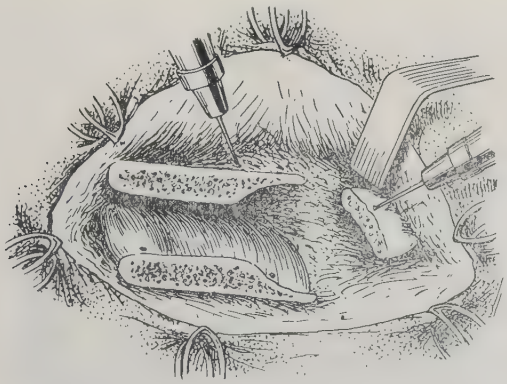


Fig. 1474.—Drilling holes in pedicled graft and bed for receiving wire suture to hold graft in place (P. P. Cole, British Journal of Surgery).

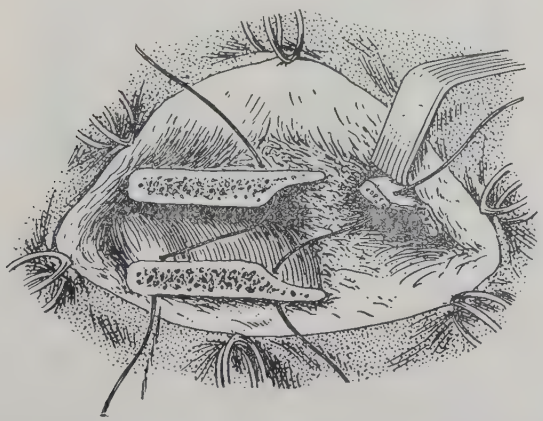


Fig. 1475.—The wires passed through the pedicled graft tightened and twisted will secure and maintain firm contact between graft and freshened fragments (P. P. Cole, British Journal of Surgery).

Fig. 1476.—The soft parts are approximated by interrupted sutures of catgut. The skin is closed and the wound is drained for twenty-four hours (P. P. Cole, British Journal of Surgery. vol. 6, p. 67).

HUMERUS

It is often difficult to thoroughly and completely immobilize a fracture of the shaft of the humerus, particularly if it is of the middle third of the bone. I have therefore presented in Fig. 1477 a method of adequate immobilization and support. This method is in quite general use and is effective.

Fig. 1477.—Fracture of the shaft of the left humerus at the deltoid insertion. Impossible to secure bony contact. Muscle interposition. Operation. Reduction of fracture. Sherman plate applied. Note the use of plaster of Paris to provide a splint which will maintain absolute immobilization and support of the distal fragment. The action of gravity, tending to distract fragments and put undue strain on screws and plate is thus eliminated. Union resulted with a functionally useful arm, elbow, and shoulder.

The reduced fracture, after operation or without open reduction, is surrounded by thin, correctly prepared and applied coaptation splints. A plaster-of-Paris splint is applied by plaster-of-Paris bandaging so as to encircle the thorax and affected shoulder and upper extremity. This splint is put on quite

snugly. The very great advantage of this form of splint is the complete support which it gives below the bent elbow. The distracting force of gravity through the weight of the forearm, tending to pull the lower fragment away from the upper fragment, is completely eliminated.

Gravity, unostentatiously and quietly acting, is a very powerful factor in causing the displacement of fracture fragments. The assistance of gravity in the reduction of fractures is recognized quite generally. Notice that (Fig. 1477) the patient, a woman, can use the wrist, hand, and fingers. She was encouraged to do so.

FRACTURES OF THE ELBOW

The *lower epiphyseal line of the humerus* is a considerable distance outside the joint line on the outer or radial side and quite near it on the inner or ulnar side (Fig. 1478).

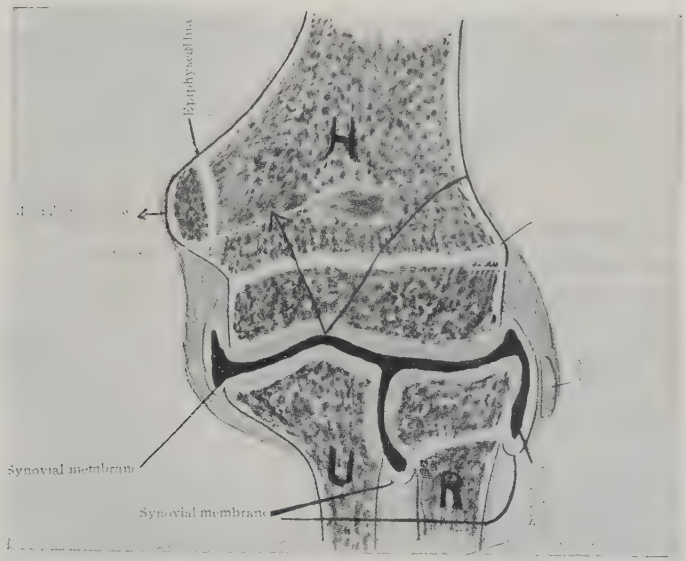


Fig. 1478.—A coronal section of the elbow-joint. The downward growth of the shaft between the medial epicondyle and the trochlear surface is well shown. The lateral epicondyle is below the epiphyseal line and belongs to the epiphysis. The medial epicondyle does not belong to the epiphysis. The lateral epicondyle is obviously the key to a safe and effective fixation of the epiphysis by pin, nail, or screw. The shaft above the epicondyle is accessible on either side along the supracondylar ridge (after Thompson).

Anteriorly and posteriorly the epiphyseal line is intra-articular. In separations of the epiphysis the external lateral epicondyle, forming a part of the epiphysis, is also displaced with it.

The *inner medial epicondyle* remains attached to the shaft. Both ulna and radius are displaced with the epiphysis.

A *nail* driven through the external lateral epicondyle into the diaphysis will not enter the joint and will hold in position the replaced epiphysis (Fig. 1478).

Certain T *or* Y *fractures* of the elbow or lower end of the humerus are really transverse fractures above the condyles with vertical fissures into the elbow-joint. They can be sometimes fixed by nails which do not penetrate the elbow-joint.

One nail may be made to enter at the external lateral epicondyle and pass transversely across the capitellum and trochlear. Another nail entering near

Fig. 1479.—Injury to the external condyle (see Fig. 1480) (Archibald Young).

Fig. 1480.—Note reduced external condyle. It is held fixed by a fine brad or sprig driven through it into the shaft (Archibald Young).

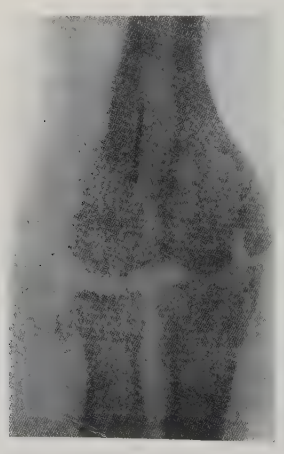


Fig. 1481.—Same elbow as seen in Fig. 1480, one year and a half after operation, showing that diaphyseal and epiphyseal growth has gone on normally (Archibald Young).

Fig. 1482.—Same as Fig. 1480. Lateral view

the first but a bit above passes upward and internally through the external epicondyle on into the lower end of the shaft.

The *lateral external epicondyle* is really the key to the treatment of these epiphyseal fractures (Thompson).

FRACTURES OF THE OLECRANON

The Operative Treatment of Fresh Fracture of the Olecranon.—Considerable disability may result after an olecranon fracture, especially if there is

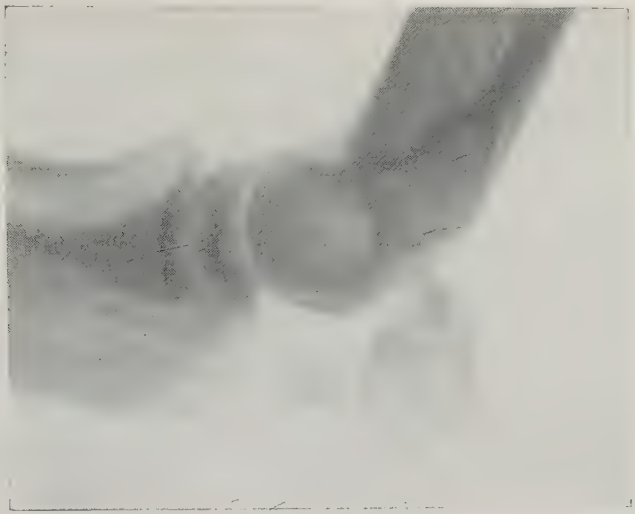


Fig. 1483.—Fracture of olecranon process of the ulna in a male twenty years old (G. F. Berg, Pittsburgh, Pa.).

Fig. 1484.—Olecranon fracture held reduced by a nail as per Roentgen ray. Same case as Fig. 1483. Perfect functional result (G. F. Berg, Pittsburgh, Pa.).

much separation of the fragments and if the lateral fascia is very considerably lacerated. In such cases, and in cases in which it is difficult to approximate the fragments, and in those cases in which associated injuries require

the elbow to be placed in either the acutely flexed position or a right-angled position, immediate suture of the fracture will be found advantageous.

If the fracture is a closed one and operation is decided upon, a wiring of the small proximal fragment to the ulna shaft through a skin incision is wise. I believe operation through an open skin incision is wiser than at-

Fig. 1485, 1486.—*a*, Incision; *b*, twist of wire; *c*, hole drilled in bone for passage of wire; *d*, fracture; *e*, passage of wire through tendon of triceps (Murphy).

tempting accurate approximation of fragments through subcutaneous means. If the fracture is an open one the compound wound can be readily utilized unless there are real contraindications.

This may be done subcutaneously, as suggested by Murphy (Figs. 1485, 1486). In subcutaneously suturing the fragments the wire is passed through the shaft of the ulna and the olecranon fragment or tendon of the

triceps by being carried into transverse drill holes which have been placed through four tiny incisions to the bone in the soft parts. The wire is twisted as the fragment approximates to the shaft and is cut and buried beneath the skin. A single suture closes each of the four tiny extra-articular incisions The elbow is then immobilized in a sling or an internal elbow splint. Active motion should be begun early after suture—as early as the end of forty-eight hours—there being no contraindications (other complicating fracture, very great joint swelling, or great damage to the soft parts about the elbow).

Associated Lesions Following a Colles or Wrist Fracture.—Rupture of the tendon of the extensor longus pollicis muscle. The extensor tendons lie in deep grooves on the dorsum of the radius and, as Ashhurst points out, they may be easily caught by adhesions and a spontaneous rupture produced a number of weeks after a fracture of the radius. This occurred in a case reported by Ashhurst. The patient was a naval medical officer, so his observations may be taken as skilled. About four weeks after the fracture of the styloid of the radius complete loss of function appeared in the extensor longus pollicis muscle. At operation for suture of the tendon complete division of the tendon was found. Subsequent recovery of muscle action was complete.

FRACTURES OF THE LOWER END OF THE RADIUS

Old Fractures at the Lower End of the Radius (Colles' Fracture).—Colles' fractures showing bony union with marked deformity should be corrected by operation, especially if the wrist is functionally impaired. Colles' fractures two or three weeks old may be refractured manually, if necessary, to correct existing deformity. The ease of refracture and the

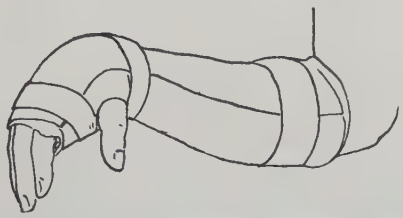


Fig. 1489.—Colles' fracture plaster splint, illustrating a position of pronation, adduction, and wrist flexion in which it may be necessary to place the hand after reduction of certain cases of Colles' fracture (M. G. H. Conference).

limits in time within which it is possible will vary with individual cases. In a recent case in a young adult the deformity can be corrected and the function improved by operative interference.

In an old fracture (three to six months or older) the anteroposterior deformity can be corrected, usually not the lateral deformity, and the pain relieved, but the function of the part cannot ordinarily be very much improved. The difficulties in each individual case and the likelihood of improving the appearance of the wrist or its function should be carefully considered before operating.

Method of Operating.—Accurate understanding of the displacement (an *x*-ray); ether anesthesia; careful preparation of the skin of the forearm and

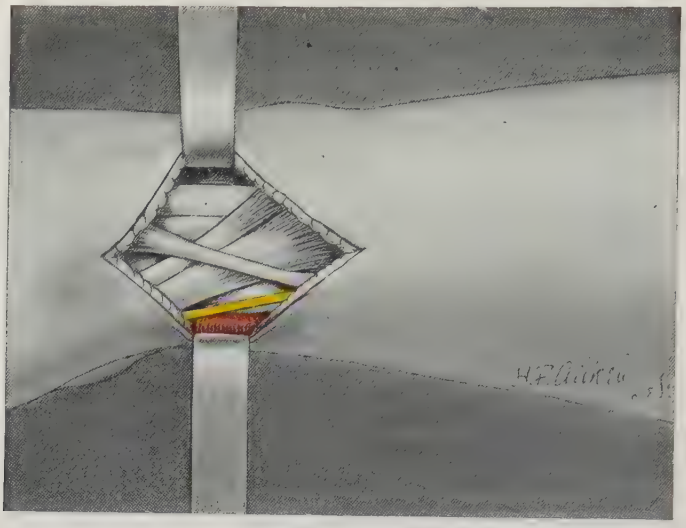


Fig. 1490.—Fracture of the lower end of the radius (Colles' fracture). Operation for correction of the deformity. The skin incision exposes the radial nerve, the extensors of the thumb and wrist. More anteriorly may be seen the radial artery.

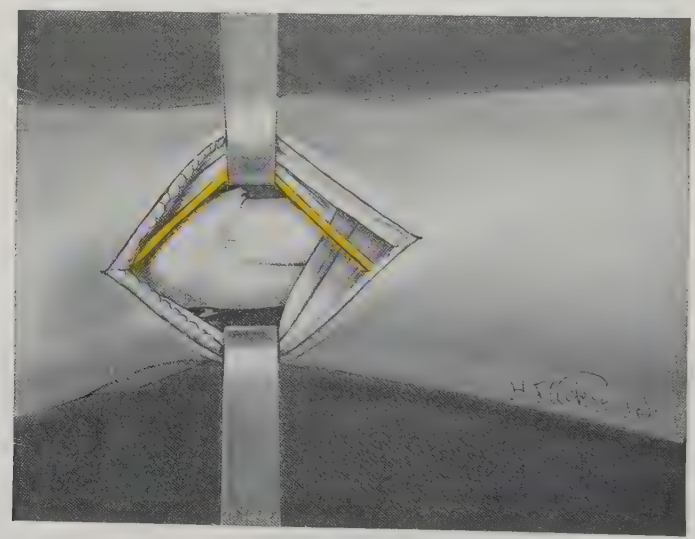


Fig. 1491.—Fracture of the lower end of the radius (Colles' fracture). Operation for correction of deformity. Note place of incision—line of fracture-deformity, distal fragment displaced backward, proximal fragment displaced forward; the radial nerve with the extensors of the wrist are retracted backward, the extensors of the thumb are retracted forward; the insertion of the supinator is exposed, beneath which lies the line of fracture.

hand; the patient's hand covered with a sterile rubber glove; a tourniquet applied over a folded towel just below the elbow, these are essential prepara-

tions for a satisfactory operation. With practice the tourniquet may be dispensed with. Rest the forearm, the hand of which is held semipronated by an assistant, on a table. Make an incision on the external surface of the wrist about $1\frac{1}{2}$ to 2 inches long, the center of which is over the fracture (see Fig. 1491). A radial vein may be encountered, which may be ligated or drawn to one side. Expose the tendons of the extensor brevis pollicis and supinator longus muscles. Approach the line of fracture in front of and behind these tendons without disturbing them much. No other tendons need be encountered or at least much disturbed. Expose the fracture, using small periosteum elevators. Keep close to the bone and expose the line of fracture for the full width of the radius front and back, reaching nearly to the radio-ulnar articulation. This is done with the retractors pushing the soft parts away from the bone without opening any tendon sheaths. By means of a small bone drill numerous perforations are made in the line of union so as almost to sever the lower fragment. The separation is then completed by means of small chisels. The retractors guard the soft parts against injury. Gentle force is used so as to entirely free the lower fragment. It will be possible now to correct the backward and forward displacement. Sometimes the position is made more satisfactory if the projecting anterior border of the lower end of the upper fragment is removed with narrow-bladed rongeur forceps. Lothrop has described this method.

The prominent ulna is an unsightly deformity. A shortening of the ulna will permit of accurate apposition of the radial fragments and will probably avoid ulnar deformity.

This shortening of the ulnar shaft is best done near to, but away from, the wrist-joint, and may be most easily done subperiosteally with the Gigli saw through a short skin incision (Darrach). It may or may not be wise to suture the divided ulna with absorbable suture to maintain accurate apposition. The wounds are not drained. Obviously, this complete operation upon radius and ulna is applicable to selected cases of old deformed fracture. Berg has lengthened the radius in appropriate cases.

The care of the wrist after operation is like the care following an ordinary recent uncomplicated fracture.

FRACTURE OF THE METACARPAL BONES

An important contribution to the surgery of the hand following fracture has been made by Mitchell. Note the case reported in the accompanying illustrations (Figs. 1492, 1493).

Non-union in Fracture of the Neck of the Femur.—Factors in Non-union: An important reason for union in fractures of the neck of the femur is the accurate reduction of the fracture. The chief reason for failure of union is non-reduction of the fracture. Unless fractured surfaces are in contact, osteogenesis will not occur sufficiently to result in union. Non-union is inevitable.

Observations on the conditions found when non-union cases have been operated on determine that interposition of parts of the capsule of the hip occurs. Moreover the capsule is found adherent densely to the proximal

Fig. 1492.—Ununited fracture of the third metacarpal bone with some loss of substance of the shaft. Before operation (A. P. Mitchell, Edinburgh).

Fig. 1493.—Result of tibial bone-graft of case in Fig. 1492 sixteen months following operation (A. P. Mitchell, Edinburgh).

fragment's irregular surface. The capsule has also been found constricted as an hour-glass between the fragments (Wilson).

Careful and difficult dissection is required to remove this fibrous tissue from the bone.

The relation of the blood-supply of the head of the bone and proximal fragment to non-union is entirely unsettled as yet (see p. 469).

In cases of non-union the bony neck of the femur is ordinarily found atrophied and partially, at least, absorbed. There is thinning of the proximal fragment and of the pelvis on the side of the fracture (Hitzrot).

It is surprising, however, how frequently the Roentgen ray will record a very considerable disappearance of the neck of the femur when on exposing the neck at operation a far greater amount of the neck will be found present than the Roentgen-ray observation would lead one to expect.

Some patients treated by the proper method are allowed to bear weight too early. Coxa vara or the complete fracture of the callus and a true non-union may result under these conditions.

Cases of ununited fracture of the hip present a pitiable handicap. Usually they get about with crutches or a crutch and a cane—bearing more or less body weight on the damaged hip. Occasionally locomotion is impossible. There is pain in going from the resting position to one of activity. There is pain in the hip at night. Further shortening and upward displacement of the distal fragment takes place as the individual moves about and uses the hip or lower extremity in locomotion. The discomfort will be greatest when the fragments of the neck are in fairly close contact. The discomfort will be least with wide separation.

The Condition of the Aged Patient.—In general, there is liable to be some mental depression, and this depression will be accentuated by the accident and the handicapped physical condition.

The Local Condition.—The limb will be atrophied. The circulation will be slow and poor in the extremity. The foot and ankle will often be cold. The knee- and ankle-joints will be limited in movement, associated with certain peri-arthritic and arthritic changes. The reparative processes will be slow. The treatment under the best conditions will be difficult and the outcome of treatment will be uncertain. The functional result at the very best will be imperfect.

Types of Cases of Non-union of the Neck of the Femur.—Old fractures with so much absorption of the neck toward the great trochanter and toward the acetabulum that the abducted position brings the shaft against the acetabulum and actually causes a separation of the fragments—no bony contact. (*a*) An exposure and freshening of the bony surfaces will be indicated and treating the fracture as a recent injury by lifting the distal fragment forward, rotating the limb inward, making traction to normal length, and abducting to the limit. All, of course, is done under an anesthetic. The angle of the neck is restored. (*b*) An autogenous bone peg may be indicated. (*c*) A stabilizing operation may be done.

Cases Untreated for Many Days After the Accident.—Much shortening is present. A little absorption has taken place. These cases can be treated by

the Cotton impaction method (see p. 515) or by simple abduction and fixation, or by bone peg into the head or into the acetabulum.

Brackett has suggested and perfected a satisfactory operation to be used in these old cases, provided no extensive osteo-arthritic changes have taken place about the joint, for if such changes have occurred a good result could not be expected, at least so far as function is concerned.

I give in Brackett's own language the description of this operation. I have employed this operation and have seen several of Brackett's results, and believe it is a useful procedure.

Fig. 1494.—Old fracture of the neck of the femur with considerable upward displacement of the femoral shaft. Exactly the type of fracture suitable for a Brackett operation.

The Brackett Operation.—The joint is best exposed by the intermuscular route, between the tensor fasciæ femoris and gluteus medius, by an incision from the anterosuperior spine to the middle of the trochanter, turning downward, parallel to the line of the femur for a few inches; then starting again at the angle of the oblique and vertical positions of the first, a curved incision is carried backward and upward 3 or 4 inches. The tensor fasciæ femoris and gluteus medius are separated, the muscle attachments on the outside of the trochanter are removed subperiosteally, or with a thin bone attachment, and the top of the trochanter removed so as to save the attachment of the gluteus minimus and pyriformis. These muscles are then

all turned backward and upward, and the upper and anterior portion of the capsule exposed, to the edge of the acetabulum. The capsule is opened longitudinally to its fibers, on the upper portion of its anterior surface, saving the attachment of the Y-ligament, if possible, but which, however, cannot always be done.

The capsule above the opening is then detached from the femur and retracted outward and backward; the trochanter cut off just below the level of the upper edge of the head, the inner portion rounded to correspond to the curve of a 1½- to 2-inch radius, saving the anterior and inner cortex. The outer portion is either cut off obliquely, or a wedge taken out, near the outer surface, allowing the outer cortex to be pushed inward. The free surface of the head is thoroughly freshened, covering this area, so as to make a corresponding curve, to the rounded top of the trochanter. In abduction of the leg, the convex surface which has been fashioned on the trochanter, is brought directly into the concaved head, and in this position is firmly held against it. In this way the femoral head with its freshened surface is placed directly on the freshened cancellar surface of the trochanter, an ideal condition for the vitalizing union of the poorly nourished fragment. The head is not placed directly on the top of the trochanter, for this would not allow the best position in the acetabulum, but on the inner and upper sides, which gives to it a somewhat oblique angle, partly resembling its normal direction, but without the normal neck. The stitches are placed in the capsule, but not tied until the leg is put into position of abduction, and the head seen to be in the relation to the end of the trochanter which is desired, in order that this contact can be assured, and the position of the leg is then maintained until the plaster is applied. The stitches are then tied; the outer attachment of the capsule which has been freed is secured with the muscle attachment. The attachments of the gluteus medius and minimus and pyriformis are either secured to the outer side of the trochanter, or are inserted into the wedge-shaped depression which has been made, in order to round off its upper and outer end. The wound should be tightly closed in layers, a plaster spica applied, including the foot of the affected and the other leg, to the knee, and extending well up to the lower thorax on the opposite side from the operated leg.

As a rule, the extreme degree of abduction is not required, and less inversion than in the Whitman method with the fresh fractures. This fixation is maintained for eight to ten weeks, fixation with an ambulatory plaster, but without weight bearing for about two months more, and beginning weight bearing with active motion at the end of this period. The ideal treatment would seem to be fixation by removable plaster at the end of the first eight or ten weeks, with beginning massage and gentle passive motion; but unless this can be carried out with very intelligent precision the complete fixation is the safer plan. The bone contact between the two fragments cannot be made over the entire surface of the head, so that considerable bridging in of new bone is necessary, for which sufficient time must be allowed, and a change in the angle of union between the tro-

Fig. 1495.—Fracture of the upper third of the femur showing abduction of the upper fragment before abduction of the limb and the lower fragment, the usual type (Pearson and Drummond).

Fig. 1496.—The same case as Fig. 1495 after abduction of the limb. Large gap still exists (Pearson and Drummond).

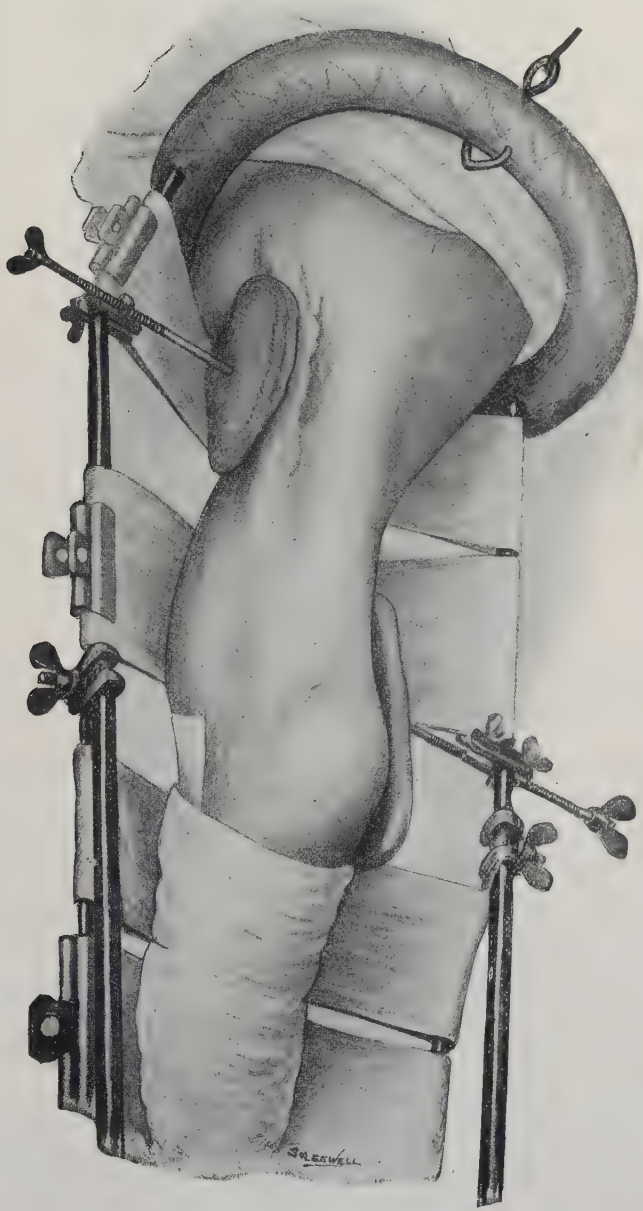


Fig. 1497.—Screw pressure pads applied as for correction of outward bowing (Pearson and Drummond)

Fig. 1498.—Roentgen ray appearances. The same case as Figs. 1495 and 1496, after the application of two screw pressure pads to approximate the surfaces. Illustrating the efficacy of carefully supervised pressure. Good union occurred (Pearson and Drummond).

chanter and head has been observed after too early motion or strain. The motion must be brought back slowly, for the capsule must be partly newly formed and newly attached, and a considerable amount of flexibility must be developed before all of the potential motion can be expected. There is no diminution in the shortening, or at least not a practical amount, for there is too much adaptive contraction of all structures to allow any decided change in the relative position of the leg to the pelvis. A greater range of motion, however, is possible than might be expected; an entirely practical amount of flexion, abduction, and rotation results. The amount of this depends somewhat on the oblique position of the head on the trochanter, and on the rounding off of its overlapping portions.

The Brackett operation may in certain patients be done perhaps more conveniently through the Smith-Petersen approach from above. The incision perpendicular plus the curved incision from the anterior superior spine posteriorly along the crest of the ilium through the origin of the gluteus medius carried to the bone. Subperiosteal removal of this flap is accomplished and the capsule of the hip-joint is exposed. In obese patients this incision is especially useful (p. 815).

The record of a case of a two-and-a-half-year-old fracture of the neck of

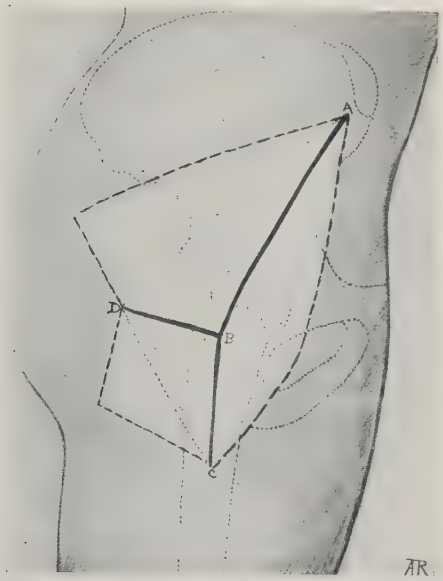


Fig. 1499.—Brackett operation, showing line for lateral and lateroposterior routes of incision with the relative position of underlying head and neck of femur: *A–B–C*, Line of lateral incision; *B–D*, posterior part of lateroposterior incision (Brackett).

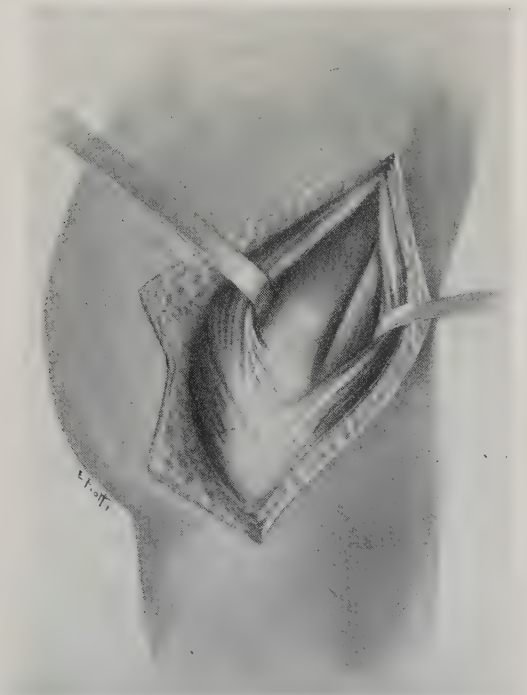


Fig. 1500.—Brackett operation, lateral route: The tensor fasciæ femoris under anterior retractor. The gluteus medius and maximus under posterior retractor. Note rectus femoris muscle lying in front of capsule of joint. Note the great trochanter. Dotted line indicates where division of the gluteus maximus may be necessary for greater access (after Brackett).

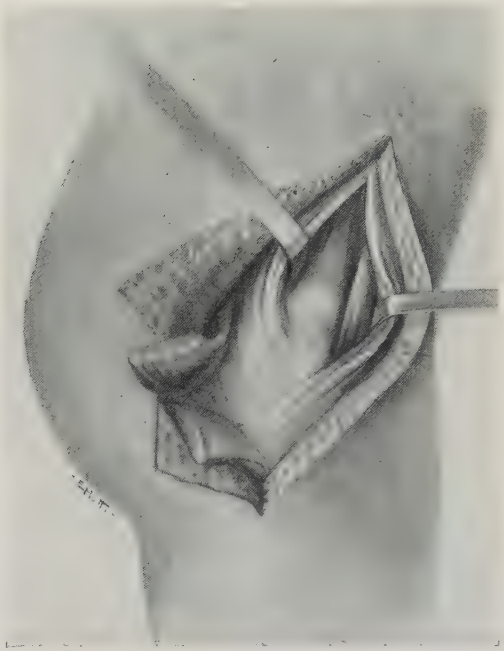


Fig. 1501.—Brackett operation: Posterior cut has been made in the gluteus maximus, further retraction of gluteus medius shows top of great trochanter and gives access to the upper portion of the heavy capsule of the hip-joint (after Brackett).

Fig. 1502.—Brackett operation: Tip of the trochanter divided and turned backward and upward with the attachment of the gluteus medius and minimus and pyriformis. The capsule of the joint, neck, and head of the femur are well exposed (after Brackett).

the left femur in a man fifty-three years of age operated by Brackett by the operation just described is of special interest.

Eight years after operation this patient is steadily at work, does not use a cane, and has only a slight limp. He does not experience any special fatigue

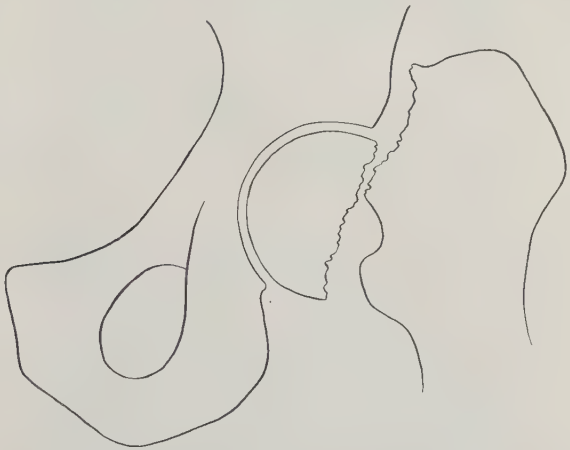


Fig. 1503.—Brackett operation: Diagram drawn from *x*-ray of fractured neck of femur (Brackett).

with ordinary exercise. He can go up and down stairs with one foot after the other (see Figs. 1506, 1507).

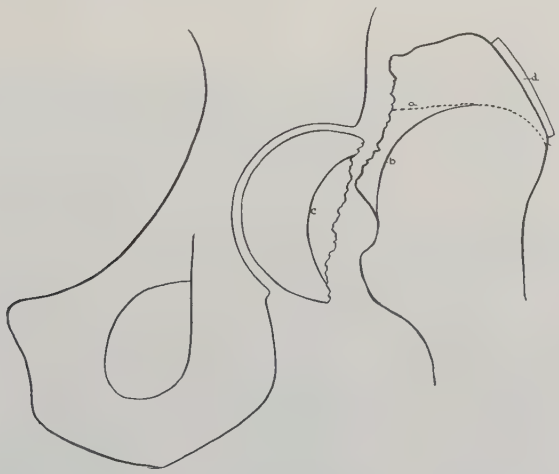


Fig. 1504.—Brackett operation: Diagram of section of bone made in operation: *a*, Dotted line on upper part of trochanter indicates level at which top of trochanter is removed. Muscles are first detached subperiosteally from the outer side of the trochanter, (*b*) to be reattached at a lower level; *c*, black line on trochanter indicates position of curve after shaping into convex surface the upper and inner extremity of the trochanter; *d*, black line indicates the curved surface after making the outer surface of the head of the femur concave (Brackett).

Examination finds slight flexion of hip. While sitting he can place left leg over the right knee but not the left ankle. He can stand on the right foot with the left foot on the seat of an ordinary chair with the left hip at a right angle. There is no limitation of motion at the knee-joint.

The advantage of the method which Brackett advocates lies in the fact that by it the normal joint structures are used in their normal relations in weight bearing.

Instead of saving and utilizing the remains of the femoral head, it may be removed and the freshened neck and acetabulum be placed in apposition with the thigh in extreme abduction. Bony union will occur between the upper end of the femur and the acetabulum. This will ultimately furnish a satisfactory limb. The tilting of the pelvis will accommodate much of the shortening. The union will be painless. Wilson thinks that this method yields a quicker result than the Brackett method. Whitman uses this latter method (see p. 852).

Speed sometimes uses the autogenous bone-peg graft inserted through the trochanter entirely through the neck, crossing the fracture line through

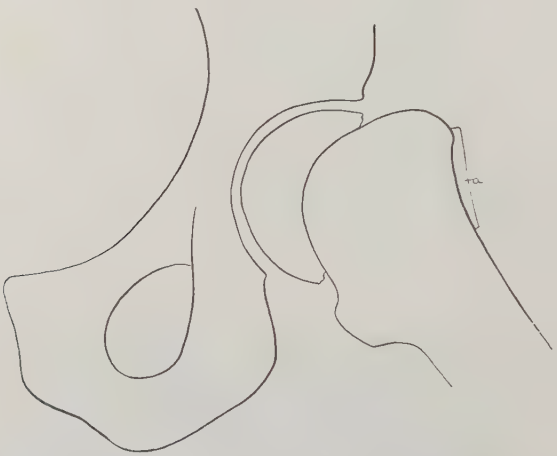


Fig. 1505.—Brackett operation: Parts in position. Leg in abduction of 50 to 60 degrees with several degrees of inversion. Convex surface of upper and inner extremity of trochanter fitting into concave surface of head: *a*, Muscles reattached to lower level on outer side of trochanter (Brackett).

the head into the acetabulum and through the deep posterior wall of the acetabulum. Thus ankylosis of the hip with union of the fracture has resulted, affording the patient a useful limb.

A hip fracture originally impacted, and this does occasionally occur, if allowed to remain impacted and otherwise properly protected, will yield ordinarily union of the neck of the bone associated with some shortening with some permanent adduction and some outward rotation of the leg as seen in the permanently everted foot.

A hip fracture occurring in a relatively young adult or in an older adult of youthful mien and good physique should not be allowed to remain apparently impacted, but should be treated by an anesthetic and gentle breaking up of the impaction by manipulation, combined with traction and counter-traction. After reproducing this, the original fracture, it is set by the abduction method. The result will be ordinarily a solid union and a useful hip.

Fig. 1506.—Brackett operation was done on this patient's left hip. Note attitude in sitting. See *x*-ray of this case in Fig. 1507, the present condition of the hip is shown (Brackett).

Fig. 1507.—Brackett operation: Roentgen ray of hip eight years after the Brackett operation (see Fig. 1506, same case (Brackett).

A hip fracture impacted in certain very old and feeble persons, and this does occur in a few cases, should not be disturbed, but left impacted. The hip should be protected so that the likelihood of a separation of the impac-

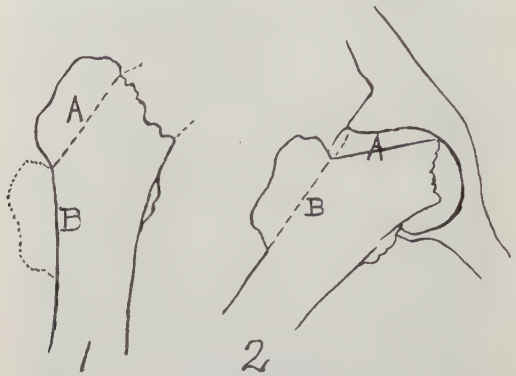


Fig. 1508.—Diagram of Whitman operation for certain fractures of the neck of the femur: Number 1, A shows the line of division of the great trochanter and No. 1, B shows the new position to which the divided trochanter is moved. The absence of the removed head is apparent. In No. 2 the operation is seen completed, the neck and refreshed trochanter stump A is placed in the acetabulum and the trochanter firmly attached (B) to the shaft. The limb is in a position of abduction. (After Whitman.)

Fig. 1509.—Case I. Result after Whitman operation in fracture of the neck of the femur. Note amount of flexion possible. Patient sits with comfort (Whitman).

Fig. 1510.—Case I. Result after Whitman operation in fracture of the neck of the femur. Same case as Fig. 1509. Note stability in walking is secured (Whitman).

tion which is usual after ten days or two weeks, if it is unprotected, will be eliminated.

Operation of Hip-joint Arthrodesis as Performed by Whitman.—I believe that the approach to the hip-joint is made best by the Smith-Petersen incision. The following are the essential Whitman operation details:

Fig. 1511.—Case I. Result one year after Whitman operation. Note abduction sufficient for stability (Whitman).

Fig. 1512.—Case II. Result one year after Whitman operation. Note sitting is possible, although degree of flexion is slightly less than in Case I. See Fig. 1509 (Whitman).

Fig. 1513.—Case II. Result following Whitman operation in fracture of the neck of the femur. Note abduction sufficient for stability (Whitman).

Fig. 1514.—Case II. Same as Fig. 1513, but posterior view (Whitman).

The capsule is opened and the head of the femur or its remnant is removed from the acetabulum. The anterior margin of the gluteus medius is followed to its insertion, and at this point, with a wide, thin, sharp chisel, the

base of the trochanter is divided in an oblique direction corresponding to the angle of the neck, and including all its muscular attachments and often a part of the capsule.

This flap of great trochanter is turned upward—out of the way. The upper extremity of the femur having been somewhat remodeled by cutting away the bony projections that are not needed, is freed from all restraining tissues and is thrust completely within the acetabulum.

It is thus placed at an angle of about 25 degrees of abduction. A space on the outer side of the shaft of the femur equal to cut surface of the retracted great trochanter fragment is freed of its cortex. The trochanter fragment is drawn downward as far as its attachments permit. The two bony freshened surfaces are apposed and held apposed by suture. The axis of the trochanter is thereby changed from a direction upward and inward to one outward and upward. Soft parts are closed without drainage. The limb is secured in this extended and abducted position by a long plaster-of-Paris spica splint.

When repair has sufficiently advanced in about four weeks the long spica is replaced by a short spica, and the patient is encouraged to bear weight, moderately at first, in order to hasten the reconstruction of the articulation by a functional adaptation of the limb to the new conditions.

When weight is borne without discomfort the support is removed and muscular control is re-established by systematic exercises.

This reconstruction operation is designed for and is applicable to cases of ununited fracture in which bone-grafting seems impracticable. This will include virtually all ununited fractures in vigorous adults.

OPERATION OF BONE PEGGING NECK OF FEMUR, UNUNITED FRACTURE

Steps of the Operation.—(*a*) Exposure of the seat of fracture through an anterior straight incision extending from the anterosuperior spine of the ilium downward for from four to six inches parallel with the external edge of the sartorius. Separation of the sartorius and the tensor fasciæ femoris makes it possible to open the space between the rectus femoris and the iliopsoas, which step will be assisted by gentle digital dissection. After division of the external circumflex artery the capsule of the hip-joint may be exposed sufficiently for the purposes of the operation. The capsule of the hip is incised and the joint space opened.

(*b*) The fracture of the neck is carefully palpated. The finger is protected by a rubber glove covered by a sterile cotton glove.

If there is any tissue between the fragments it is removed.

(*c*) The surfaces of the fracture fragments of the neck of the femur are refreshed by knife, chisel, or curet.

(*d*) The autogenous tibial graft is obtained at least 5 inches long and fully $\frac{1}{2}$ inch thick. A beef bone peg is less satisfactory.

(*e*) A vertical incision exposes the outer side of the great trochanter near its base.

(*f*) A hole is drilled ($\frac{3}{8}$ inch twist drill) through the base of the great trochanter, emerging at the seat of fracture.

(*g*) The thigh (distal fragment) is pulled down, abducted, rotated inward (Whitman position). Apposition is secured as nearly as possible between the two fractured surfaces.

(*h*) The drill is then carried across the plane of the fracture about 2 inches further (deeper) into the head fragment.

(*i*) The drill is carefully removed while the limb is held fixed by an assistant in the correct position.

(*j*) The autogenous tibial peg graft, irregular in shape with slightly pointed end, is placed in the drill hole and is hammered into the neck and head of the femur.

(*k*) The projecting end is cut off flush with the cortex of the great trochanter. The properly protected finger in the anterior wound confirms the suitable placement of the bone peg.

(*l*) The wounds are closed without drainage.

(*m*) The position of the fragments and the relation of the bone peg to them is determined by the fluoroscope and the Roentgen-ray record plate.

(*n*) Considerable care should be taken in handling the limb while it is being immobilized. The peg may be fractured.

(*o*) *After-care.*—A plaster-of-Paris splint spica is worn for eight weeks. The limb may be adequately suspended in abduction in a Hodgen splint.

(*p*) Then a convalescent Thomas caliper splint should be used with crutches.

(*q*) No weight bearing should be permitted for at least six months, and then at first protected by the Thomas caliper splint.

Henderson secured fifteen successful results from 26 cases done by the above method.

Campbell secured fourteen successful results from 20 cases by the above method.

FRACTURE OF THE SHAFT OF THE FEMUR

Operative Treatment (see p. 753.)—This covers all long bones.

Postoperative Care in a Thomas Splint as Used in the Sherman Clinic, Pittsburgh.—After operation on the shaft of the femur the lower limb is placed in a Thomas splint to which a Pearson knee-flexion splint is attached.

The thigh and leg are placed in flexion (the position of muscle balance and greatest relaxation). The knee is flexed to about 45 degrees. The thigh and leg are attached to the Thomas splint by the usual slings and a bandage covers all securely (Fig. 1515).

The *splint is slung* from the Balkan frame. Massage, active and passive motion of the knee are begun on the fourth day and continued daily until the patient can, himself guardedly use active motion safely (Fig. 1517). The lower limb is removed from the splint about the eighth week.

A walking Thomas caliper is applied for a few days before the patient leaves the bed. The active motion of hip, knee, and ankle is encouraged during this time and before getting up from the bed.

About the ninth week the patient is up learning to walk between crutches with the Thomas caliper splint applied.

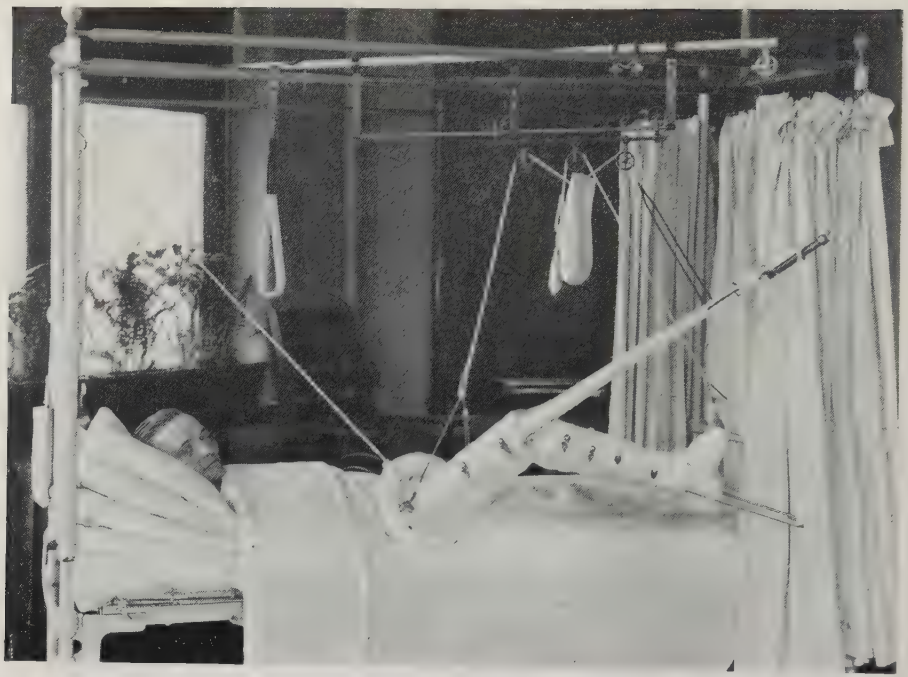


Fig. 1515.—Plated femur case immediately after operation (Sherman). Note Thomas splint, Pearson attachment—balanced suspension of splint.

Fig. 1516.—Same case as Fig. 1515 two weeks after operation (Sherman). Note suspension of foot allowing voluntary ankle movement. Active motion, guided, of knee-joint.

Fig. 1517.—Four to six weeks after operation, showing flexion. Note complete extension of knee-joint (Sherman).

Fig. 1518.—Same as Fig. 1515, but showing active and passive motion controlled by the patient (Sherman).

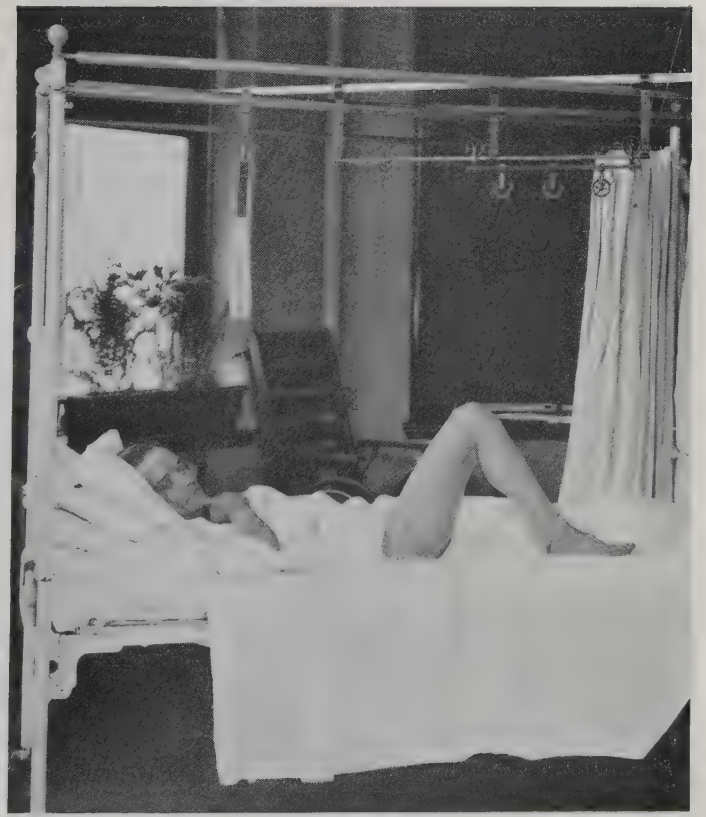


Fig. 1519.—Six to eight weeks after operation, patient in bed, leaving off all splints. Note active flexion of knee-joint (Sherman).

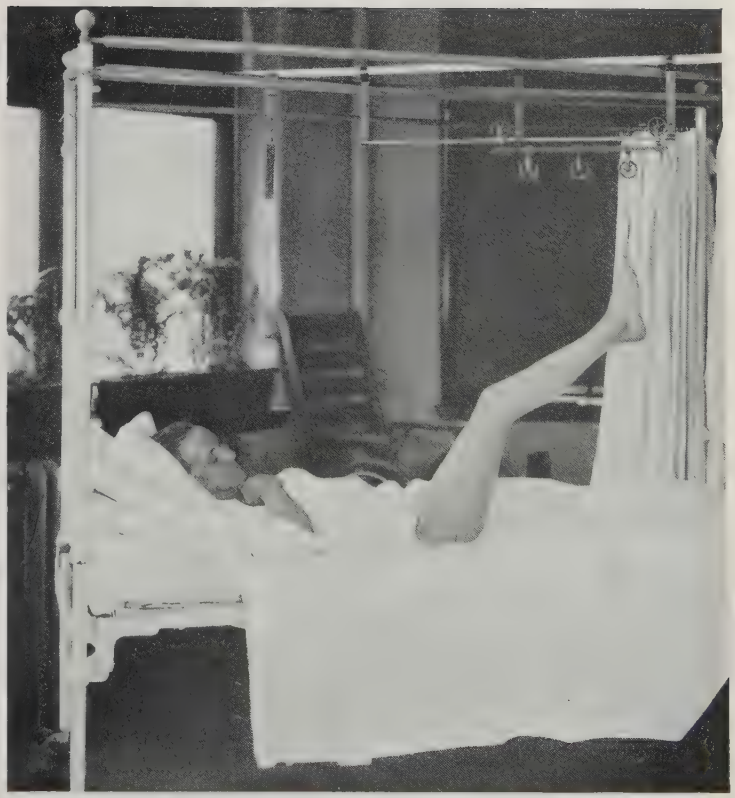


Fig. 1520.—Six to eight weeks after operation, patient in bed, leaving off all splints, showing range of motion at hip and knee-joints (Sherman).

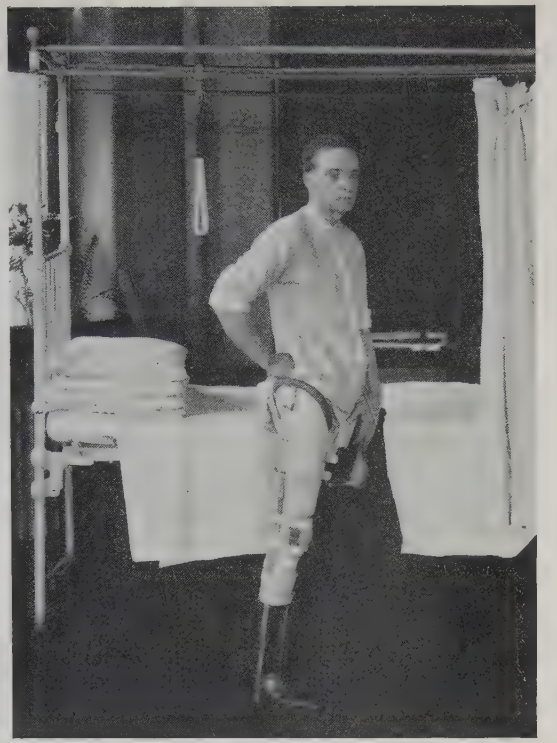


Fig. 1521.—Same case six to eight weeks after operation, but showing caliper (Sherman).

Fig. 1522.—Same case four and a half months after operation, showing caliper off, and patient ready to return to work (Sherman).

The splint is worn for twelve to fourteen weeks after leaving the bed.

The splint after the ninth week is omitted at night, and applied on getting up in the morning.

Motion at the Knee-joint.—When the patient leaves the bed he ordinarily has from 45 to 90 degrees of knee flexion from the completely extended position. Knee flexion continues to increase. In from five to eight months following the injury there will be full voluntary flexion and extension at the knee.

In order that the results of the operative treatment of fractures of the shaft of the femur as obtained in an ideally conducted clinic might be recorded here as a standard, I have tabulated the cases from the clinic of Sherman, Pittsburgh, Pa.

These cases are unselected. The actual details of the operation and after-care are explicitly stated in the preceding pages. The summary of results is here recorded:

TABLE 1

FRACTURE OF THE FEMUR: OPERATION. RESULTS. (Sherman Clinic, Pittsburgh, Penna.)

Number of cases.		Complete immobilization, days.	Partial immobilization, weeks.	Ambulatory, weeks.	Away from job, months.
35	Adult closed.	7½	7¼	7½	6 (average)
5	Adult compound.	17½	7¾	5	8.5
3	Ununited.	14	7	8	12
3	Children.	12	7	5	4

TABLE 2

TIME AWAY FROM JOB (BY MONTHS) OF THE ADULT CASES ABOVE TABULATED

No. of cases.	Months.
1	2
2	3
6	4
7	5
4	6
6	7
2	8
2	11
1	12
1	13

These postoperative results are illustrative of what is accomplished under ideal surgical conditions. It is a splendid record.

These results are to be compared, of course, with those obtained under similarly ideal conditions and in a like group of patients by the non-operative treatment (see p. 557).

Fracture of the Femur. Postoperative Care, Magnuson Clinic, Chicago. —*A Bit of Detail of After-care of Operative Femur Cases.*—Plaster-of-Paris spicas are applied from the pelvis to below the knee, usually two-thirds the distance down the lower leg. Fractures above the lower and middle third are completely immobilized for ten days to two weeks. Then a U-shaped piece is removed from the posterior part of the plaster splint, up as high as the flexor surface of the knee. This leaves protection anteriorly and laterally. Twice a day the knee is moved by turning the patient on his side, or lifting him on a fracture frame. No considerable amount of force is used, just a gradual, steady stretching. This passive motion is kept up and increased daily up to the time of removal of the cast to above the knee, which is usually about five or six weeks. The patients who are strong enough to handle themselves and get around on crutches are allowed up with a high-soled shoe on the foot opposite the fractured limb, in from ten days to two weeks.

The plaster splint is usually removed entirely at the end of six to eight weeks; an *x*-ray taken without the splint to determine the amount of callous formation. If there is not sufficient callous formation to warrant allowing the patient to be up with a high sole on the opposite foot without support, another plaster-of-Paris splint is applied, usually a short one, from the pelvis to above the knee, and the motion of the knee continued for from two to four weeks longer. The handling of the case depends somewhat, of course, on the weight of the patient and his ability to form callus.

No intern or assistant is allowed to handle the patient when the splint is first removed. It is cut, patient taken to the *x*-ray room, and the operator personally supervises having the leg lifted out of the splint and the *x*-ray taken, without allowing any tendency to displacement, if there has been insufficient callous formation. In this way movement at the fracture is avoided, if only a small amount of callus has formed; and there is no damage done. The average individual does not appreciate the fact that traction in a direct line with the long axis of the fractured bone when lifting is essential to prevent angulation.

The splint is not removed until there is enough hard callus to maintain the fracture in position. Weight bearing is allowed gradually, first with the support of crutches and then with the support of a cane; but by the time weight bearing is allowed the patient's knee is entirely normal in motion, and in many cases the hip is entirely normal in motion because of the treatment immediately following the fracture.

Fractures below the middle third cannot be allowed to have knee motion as early as those above the lower third, of course; but usually knee motion is attempted in between three and four weeks in the same way as that applied to fractures above the lower third, the only difference being that in fractures of the lower third a heavy pad of felt is put anteriorly and posteriorly over the site of the fracture at the time of applying the first splint, so that the plaster may be pulled very much more snugly around the site of the fracture, leaving the sides without pressure so that there may be no blocking of the circulation. In this way it has been found that motion of the knee can be

started much earlier than it can be done with simply applying the plaster of Paris around sheet-wadding, as is the usual custom.

Of course the tendency to displacement in fractures of the upper third is angulation toward the external surface of the leg, whereas, angulation of the lower third is in the anteroposterior plane, which would be true if one started to flex the knee early. Therefore, support, especially on the anterior surface in these low fractures of the femur, is especially important.

In an uncomplicated operated fracture of the shaft of the femur in an adult there can reasonably be expected about 5 to 15 degrees of flexion on the tenth day after operation. At two weeks there will be about 45 degrees of voluntary motion. At eight weeks there will be about 90 degrees motion, *i. e.*, at the time the plaster splint is removed.

Some weight bearing is allowed in nine weeks. Complete weight bearing is permitted in ten weeks, using a cane. Unsupported weight bearing in

Fig. 1523.—Patient thirty-five years old. Compound supracondylar fracture of both femora and compound fracture of upper third of both tibiæ. Fractures did not extend into knee-joint. Date of accident November 17, 1924. On wheel chair May 12, 1925; began to walk May 20, 1925. Sherman plates and screws used. Approximate motion of both knees 75 per cent. Very complicated case. Brilliant result. Restored to usefulness (Berg, Pittsburgh).

three months is the routine result. All patients have had 90 degrees of voluntary flexion at the end of three months.

Following operative fixation of a fracture of the shaft of the femur, Eliason, Philadelphia, uses postoperative traction through a Steinman nail or caliper to the condyles of the femur, believing that he thus tends to overcome muscle spasm which may angulate or unduly strain the seat of fracture. He also uses drainage in the operation wound for forty-eight hours. He does not remove the steel fixation plate unless compelled to. I personally have not found postoperative traction or drainage necessary in these cases.

Berg, of Pittsburgh, conducts a clinic of very serious fractures. Cases in this clinic present most complicated injuries. The accompanying case (Fig. 1523) is recorded here to illustrate what may be expected in severe

injury to the femora treated ideally. These results indicate the goal to be attained by operative methods.

Intracapsular Fracture of One Condyle of the Femur.—A fracture was reduced immediately by Sutcliffe[1] by operative approach on the inner side of the knee-joint posterior to the patella.

The condyle was displaced backward and partially rotated on its transverse axis. A steel plate was used to hold the fragment replaced. A normal knee resulted. The sutures were removed in fourteen days. Massage and active and painless passive movements used at three and four weeks. The patient was eleven weeks in the hospital.

This case illustrates well the result to be expected where good judgment and careful technic are used in the greater joint fractures. Immediate accurate reposition should be sought. Early active and painless passive motion should be used.

OPERATION FOR FRACTURE OF THE PATELLA

Local Preparation.—The skin should be sterilized for a wide area above and below the knee-joint. The sterilization should extend above to the level of the perineum in the thigh and below to the ankle. Especial care should be exercised in the detection of any unhealed abrasions or pustules or blebs of the skin of the region exposed in the preparation. No operation should be done until these danger spots are healed or are suitably covered, so as not to be sources of infection.

Incision.—An incision to adequately expose the fractured patella and all damaged parts (fasciæ torn) should be made. The shape and extent of this incision best suited to the situation is usually one slightly curved with the convexity downward. The cicatrix of this incision will not be pressed upon subsequently when the patient kneels because the level of the lowest point of the incision is above the part of the flexed kneeling knee which comes in contact with the ground.

The straight transverse, the longitudinal, the curved with convexity above, these incisions have all been used. The least advantageous one for access to fracture of the patella is the longitudinal, for it is absolutely essential that the incision afford an easy approach to the torn capsule of the knee on either side of the fractured patella.

The longitudinal incision in the median line cannot possibly afford such access without very great dissection of the subcutaneous tissues or additional lateral incisions.

Because of the very tough and fibrous character of the quadriceps tendon above, and the same character of the patellar ligament below, it is possible, by passing a wire suture through the patella, across and over the patellar ligament, back through the patella, twisting the wire over the quadriceps tendon, to keep the fragments of the fractured patella in position, at the same time allowing mobilization of the knee.

[1] British Journal of Surgery, January, 1925, p. 450.

Procedure.—The joint surfaces, the fractured bone, the laterally torn fasciæ are all exposed to view. All clots of blood are washed away by irrigation with sterile salt solution. This is the gentlest method of removal of clots. Gentle gauze wiping, but very gentle, will assist in the irrigating.

Any tiny loose fragments of bone are removed. Torn overlapping fascial shreds which cover the fractured surfaces of the patella are carefully lifted off the fracture and retained for subsequent inclusion in the suture of the capsule (see Fig. 1160).

The bony fragments are brought into apposition. If the fracture is transverse or only slightly comminuted, the patella clamp (see Fig. 1527) may

Fig. 1524.—Illustrating the long median longitudinal incision in the approach to the knee-joint (Allison).

be used to tightly approximate and hold the fragments together while the suture is being placed.

I have devised and used for several years a patella clamp. This clamp is shown in Fig. 1527. Obviously, if the fragments of the patella are firmly brought together before the absorbable or non-absorbable sutures are finally tightened, the apposition of the fragments, especially when but two fragments are present (as so often is the case), is made pretty accurate. This clamp is not used in every case, but I have found it at times convenient and helpful. It is unwise to attempt to pull fragments together by sutures. The fragments should be approximated and held fixed, then the sutures tied. This

clamp helps to hold the fragments of the broken patella temporarily approximated. Berg has modified the Scudder patella clamp.

Old Fracture of the Patella.—Occasionally it is necessary to repair a fracture of the patella which has been broken some time previously, several months perhaps. A varying amount of difficulty attends the attempt to bring the upper fragment down to the lower fragment. Obviously an incision is necessary. Three ways of accomplishing this have been found effective: (*a*) By a transverse incision of the fascia over the rectus and of the rectus itself; (*b*) by several lateral transverse incisions either alone or

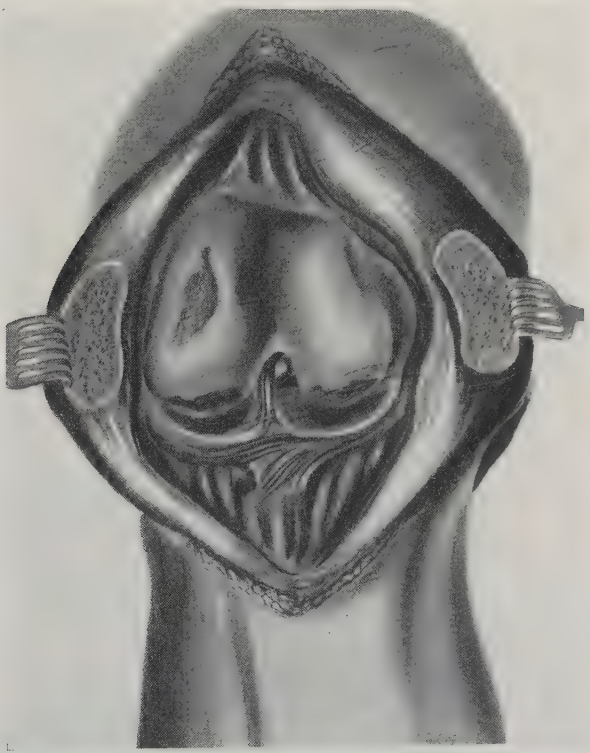


Fig. 1525.—Illustrating the accessibility of the knee-joint through this approach shown in Fig. 1524. Note retraction of split patella and internal ligaments of the knee and the possibility of reaching fractures of the condyle of the femur and supracondylar fractures entering the knee-joint (Allison).

together with a median transverse incision of the thigh fascia; (*c*) by reflecting a flap of the quadriceps fascia downward and so suturing it as to bridge the gap between the upper and lower fragments of the patella.

By this latter procedure (*c*) little attempt is made to approximate the bony fragments, but the gap is filled by a strong fascia.

Suture of Parts.—(*a*) The bone is to be held securely. (*b*) The capsule of the joint is to be closed. (*c*) The torn fascial soft parts are to be approximated. (*d*) The subcutaneous tissues are to be closed. (*e*) The skin is to be brought together.

The bone is drilled (each fragment). Two holes are then drilled in either fragment, whichever happens to be the larger, or if one is comminuted and the other is not so badly comminuted, through the one which is the least broken. The drill is pointed obliquely backward, toward the popliteal space and toward the line of fracture, and is carried across the line of fracture so that it marks on the opposite fragment its exit from the bone into the line of fracture. The fragments are then separated so that the operator can again drill through the smaller or comminuted fragment a hole which corresponds in angle with that just described, and pointing backward in the same way it comes out at the drill mark previously made by the line of fracture. This

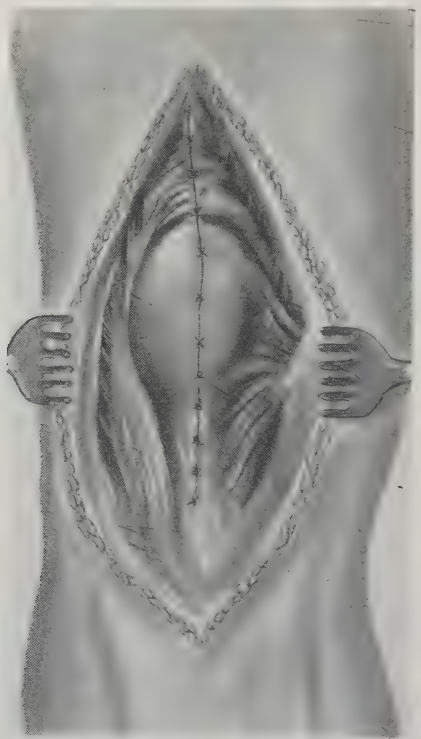


Fig. 1526.—Illustrating closure by interrupted suture of the fascia, thus approximating the divided patella fragments (Allison).

is repeated on the opposite side. In comminuted fractures the holes may be separated until they approach the sides of the patella so as to make practically a purse-string through the bone. The wire is then passed through the holes from top to bottom, over the patellar tendon, up through the opposite two drill holes; the fragments are then put into perfect apposition and clamped in place, the wire pulled tight before twisting, so that the wire between the two lower drill holes fits tightly over the patellar tendon, and the wire is then twisted with a sequestrum forceps or other strong instrument until it is pulled as tight as is consistent with pressure over the tendons above and below—Magnuson (see Fig. 1528).

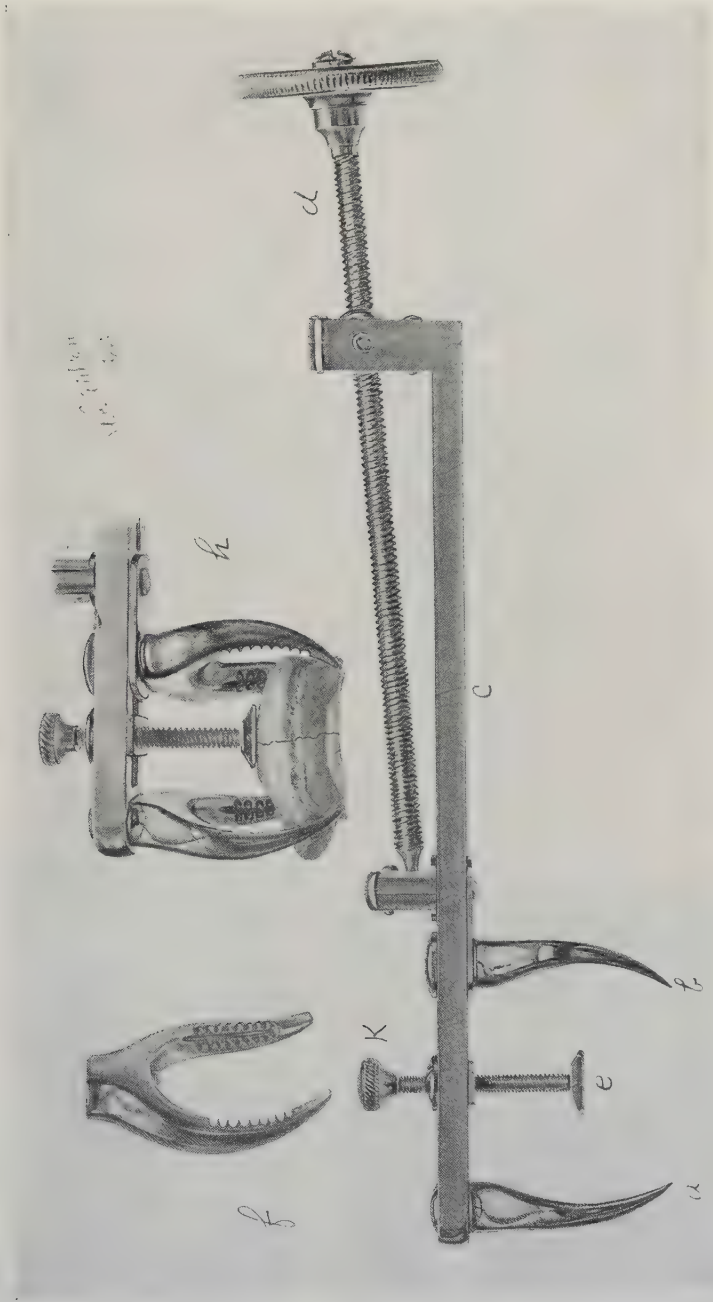


Fig. 1527.—Patella clamp devised and used by Scudder in fracture of patella. See text. *a*, A jaw fixed excepting for rotation; *b*, a jaw movable along bar *c* by screw *d*; *e*, plate adjustable on horizontal bar *c* and to upper surface of fragments (see *h*); *f* shows jaw in oblique view; *h*, the two jaws engage patella.

Material Used in Suture of Patella.—Whether non-absorbable or absorbable material is used in suture of patella is an important matter.

Non-absorbable materials, ordinary malleable iron wire, is used (Magnuson). This has great tensile strength and will not twist off or break as is the

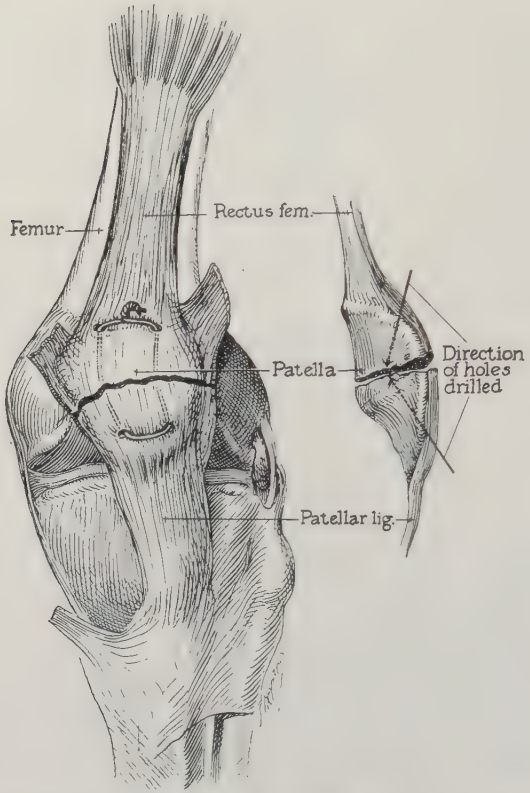


Fig. 1528.—Diagram illustrating method of drilling patella for insertion of iron wire (Magnuson).

Fig. 1529.—Fracture of the patella. Case treated by iron wire suture of patella. Suture *in situ*. Note degree of voluntary extension (Magnuson).

Fig. 1530.—Fracture of the patella. Note flexion to a right angle a few weeks following suture of patella with iron wire (Magnuson).

case with other types of wire, such as silver; it is large enough so that it does not cut the ligament over which it is stretched tight unless undue pressure is put on it, and can be trusted to withstand all the pull the quadriceps will make upon it in the ordinary course of future treatment.

Silver or aluminum-bronze wire (Hawley) afford close approximation. Hawley, of Bridgeport, Conn., has consistently followed and advocated early operation of fracture of the patella by suture with aluminum-bronze wire. He has likewise happily employed early active guarded movement of the knee. He has permitted the patella patient to bear weight very early after operation—see legends of Hawley's cases. This experience of Hawley goes far to perfect the treatment of patella fracture. It must be noted that

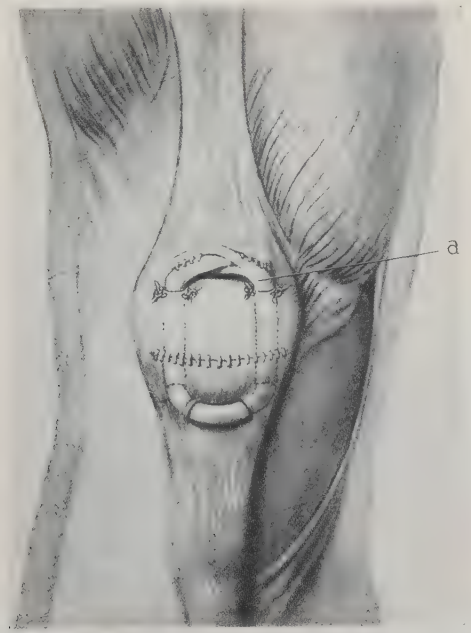


Fig. 1531.—Operation for repair of an ununited fracture of the patella in which one of the fragments is very small: *a*, Heavy suture of fascia lata passed vertically through the patella and transversely through the ligamentum patellæ. (Gallie, British Journal of Surgery, vol. xii, 1924.)

all this freedom of early motion and omission of joint support in Hawley's method of treating this very important joint fracture is very carefully supervised by the surgeon himself or especially skilled assistants. The results are very close to ideal. The method in the hands of any but skilled surgeons is dangerous. Undoubtedly the wire allows early movement before the bony union will hold the fragments from separation when movement is made.

Non-absorbable material is tolerated by the tissues and removal is not always obligatory.

I believe if wire is used it should be subsequently withdrawn after it has served its purpose. I see no good reason for leaving it in place, and I know certain cases in which it has caused disturbances.

The occasional necessity for the removal of the wire or the predetermined and established policy of withdrawing the wire after it has accomplished its purpose do not militate against the employment of a non-absorbable suture of the patella. A possible second operative maneuver is of no objectionable importance compared with the absolute integrity of the part free from any and all possible menace. The contenders for leaving the suture in place, in this relatively superficial area, must admit (common experience) the occasional forced removal. This occasional compulsory removal is the determining factor in the establishment of a sane procedure. To "take a chance" is

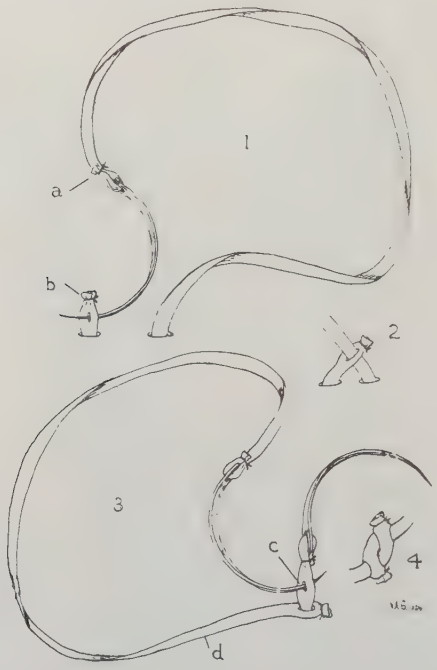


Fig. 1532.—Diagrams illustrating points in the technic of using living sutures of fascia: 1, The strip of fascia lata has been tied into a large-eyed needle with fine silk (*a*), and a similar ligature has been tied around the tail of the suture at *b*. The needle has been passed through some strong aponeurotic tissue and then through the tail of the suture to form a slip-knot. 2, The slip-knot drawn taut. 3, Method of joining one suture to another. The suture (*c*) has been used up. The needle of suture *c* is passed through the tail of suture *d*, and the needle of suture *d* is then passed through suture *c*. The needle of suture *c* is cut off, and suture *d* is drawn taut. 4, The jointing of the two sutures completed. (After Gallie, British Journal of Surgery, vol. xii, 1924.)

poor surgery. To trust that the individual case is not to be the one in question is in my opinion too great a chance from the patient's standpoint solely.

Remove all non-absorbable sutures used in fracture of the patella after union is firm and secure.

Absorbable Suture of the Patella.—In the use of absorbable material, whether chromic catgut, kangaroo tendon, or autogenous fascial strips, the object is to approximate bony fragments and to trust to the suture merely to hold the approximation secured. Perfect results have followed both kinds of suture material. The explanation for these final equally good results lies in the

fact that absolute bony contact with bony union is not always essential in fracture of the patella to give perfect functional results. A fibrous tissue close union will be as serviceable as absolute bony union, other things being equal.

I have personally used for many years absorbable sutures in the patella or about it. I have not often drilled the bone for the placing of these sutures.

The result following this absorbable suture method is slow but satisfactory.

I am inclined to believe that by using the wire suture with our present technic closer approximation of the fragments is maintained at the time of the operation and that earlier active motion may be more safely used than with the absorbable suture. The outcome of the case with wire suture will therefore be early weight bearing, early movement of joint, more uniform bony union, a stronger joint, a more nearly normal range of motion.

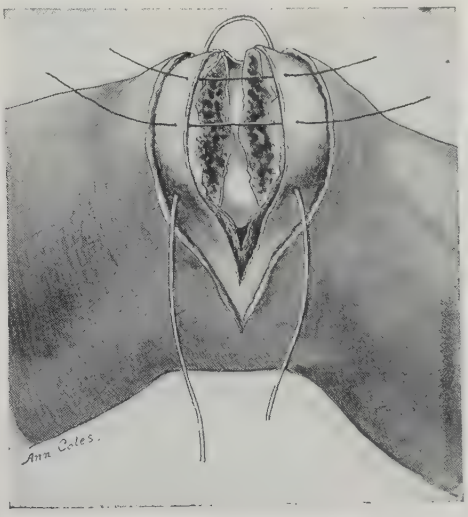


Fig. 1533.—Repair of fractured patella by a loop ligature of wire, kangaroo tendon, or silk, carried through drill-holes made transversely through each bone fragment. The margins of the overlying and laterally placed periosteo-aponeurotic structures are brought together by suture. (From Bickham, Operative Surgery, vol. ii.)

There will always be individual cases by each method which do ideally. In suture of the patella adopt the method that appears to be yielding that result which is desired in the case in hand, and which is most suited to the special case.

I approve of the wire suture and very early mobilization.

I approve of the absorbable suture and very early mobilization.

Suture of the Soft Parts.—There should be no joint drainage supplied. The capsule of the joint and the immediate pericapsular tissue combined are sutured so as to close the knee-joint, using a fine absorbable catgut (o or No. 1). The fascia of the knee so widely torn is approximated with care by interrupted absorbable sutures. The skin wound is sutured. The skin is carefully cleansed, all blood being removed from the neighborhood of the skin wound.

The Dressing.—A dry gauze dressing is applied so as to cover fully two handbreadths away from the wound. This dressing is held by a bandage. The size and thickness of the dressing together with a supporting pillow help to somewhat support the knee-joint.

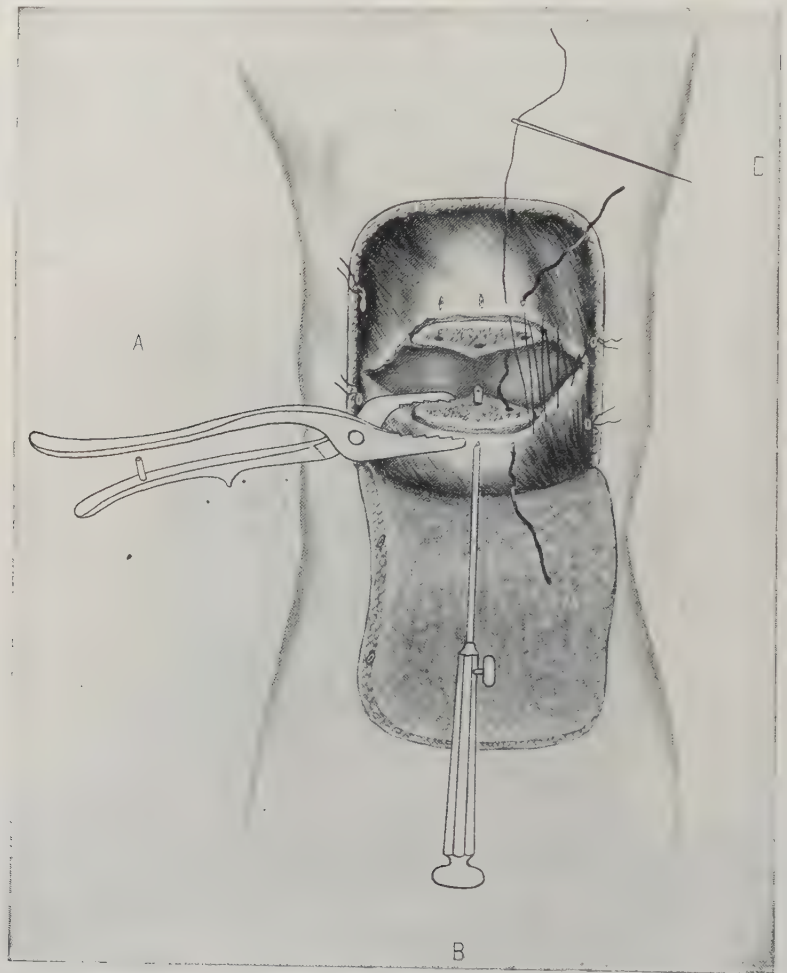


Fig. 1534.—Operation for fractured patella by wiring: A, Lower fragment of patella steadied with bone-holding forceps; B, drill in act of making holes for passage of silver wire, one piece of which is seen in position; C, chromic gut suture of torn capsule and fibroperiosteum. Note one end of the wire is incorrectly represented passing into the joint. (From Bickham, Operative Surgery, vol. ii.)

The suspension of the extremity in a Thomas splint is helpful, with the Pearson leg support, when needed. There is no need to rigidly immobilize the knee-joint. In fact, it is decidedly better not to.

After Operation. Course of the Fracture.—There will be some swelling of the knee-joint for a few days following the operation. The dressing retentive bandage should be loosened and reapplied to adapt the extra-articular pressure to the intra-articular distention. The patient is encouraged to flex the

knee slightly while lying in bed. About forty-eight hours after operation massage, active and passive motion up to about 15 degrees is instituted.

Motion, active and passive, is gradually increased until at the end of six weeks 90 degrees of motion should be possible without pain, and the patient should be able to raise the leg almost in line with the thigh at this

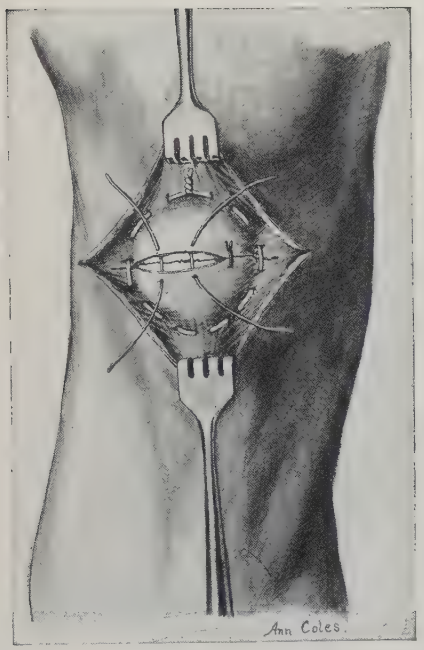


Fig. 1535.—Operation for fracture of the patella by an encircling suture of the soft parts by wire, kangaroo tendon, or silk. All tissues intervening between the fragments are cleared away, and the encircling ligature passed deeply into the quadriceps extensor tendon, tendon of the patella, and lateral tendino-aponeurotic structures. Interrupted or continuous catgut sutures pass through the margins of the tendino-aponeurotic covering of the patella. (From Bickham, Operative Surgery, vol. ii.)

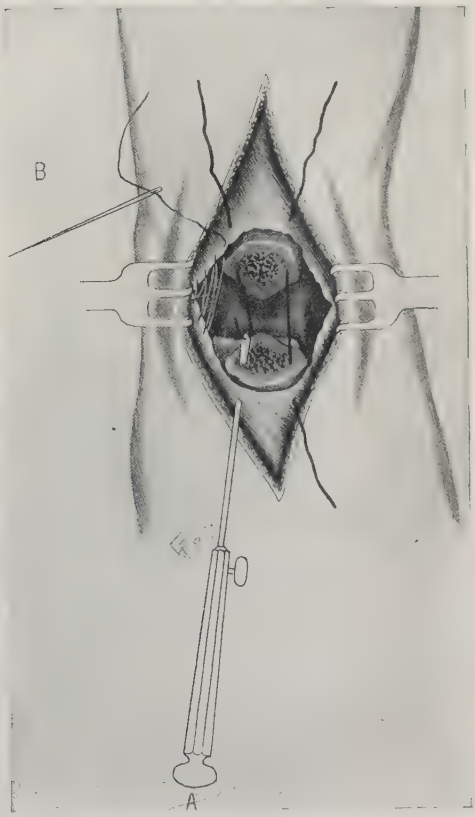


Fig. 1536.—Operation for fractured olecranon by wiring: A, Drilling holes for passage of silver wire, one suture being seen in position, and one being drawn through; B, chromic gut suturing of torn capsule and fibroperiosteum. (From Bickham, Operative Surgery, vol. ii.)

time without assistance. This operation does away with the long-continued disabilities following operation for fractured patella. It does not allow the quadriceps to atrophy, and will allow the patient to return to practically any type of work in about two months from the time of operation.

The above procedure is essentially that followed by Magnuson. Note the results obtained and the short incapacity following this method.

Gallie[1] found the use of transplanted strips of fascia lata so successful in treating habitual dislocation of the patella laterally that he used the method in ununited fracture of the patella successfully. He was led to use this suture in these cases also because of the gap to be filled between the widely separated fragments which in certain cases cannot be even approximately brought together. One fragment may be very small.

Technic of Operation.—The drill holes are made in the large fragment only and the loop of fascia lata is drawn through the quadriceps tendon or

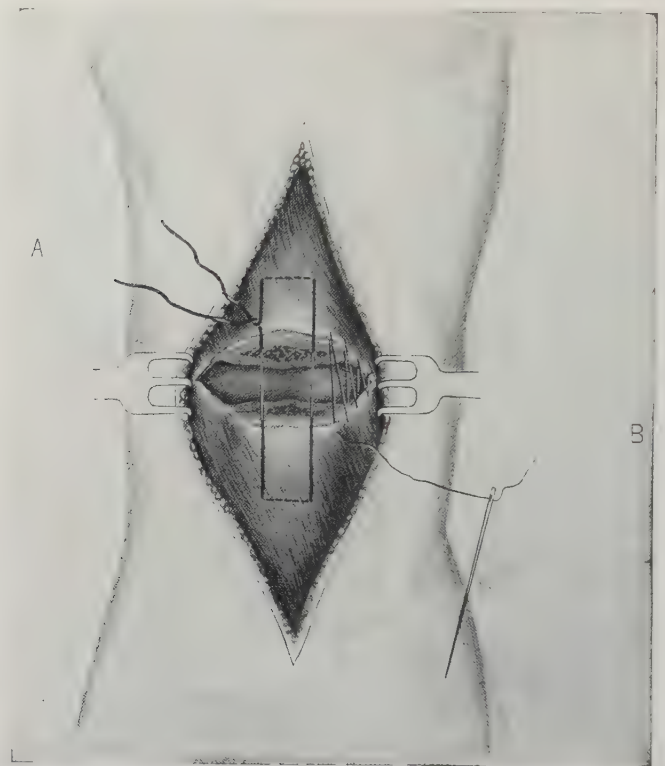


Fig. 1537.—Operation for fractured patella by Stimson's method of mediate suture: A, Heavy silk suture (of mattress variety) passing through greater thickness of quadriceps extensor tendon, above, and ligamentum patellæ, below; B, chromic gut suture of torn capsule and fibroperiosteum. (From Bickham, Operative Surgery, vol. ii.)

the ligamentum patellæ (according as the small fragment is above or below) through a transverse tunnel made with a narrow knife. The presence of the small flake of bone in the end of the tendon prevented the loop from cutting out.

The transverse rent in the lateral expansion of the quadriceps tendon and the capsule of the knee is closed with a living suture of fascia threaded on a needle. The success of this operation by Gallie was complete. (See Fig. 1532, illustrating the method of fastening fascial strips into the needle.)

[1] British Journal of Surgery, vol. xii, No. 46, 1924.

Fig. 1538.—Roentgenogram of old fracture of the patella in a man aged thirty years. Before operation (Phemister, Annals of Surgery, December, 1915).

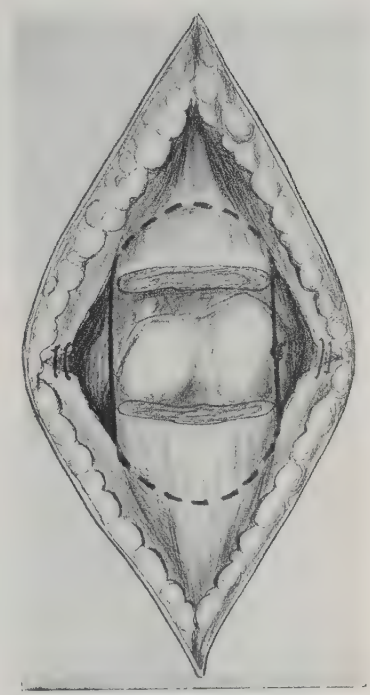


Fig. 1539.—Fragments encircled by silk suture and capsule sutured laterally (Phemister, Annals of Surgery, December, 1915).

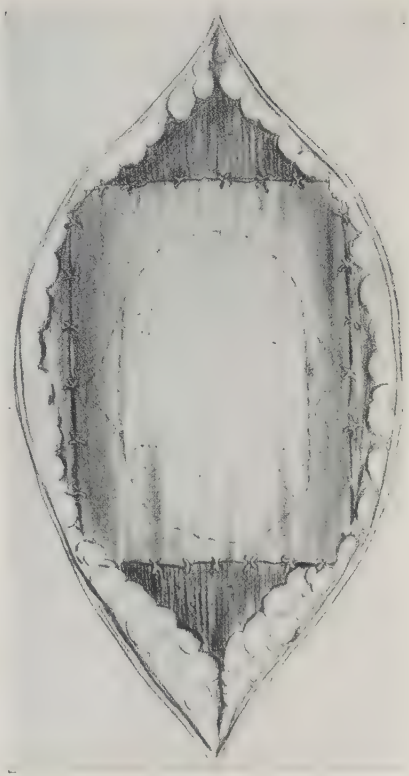


Fig. 1540.—Fascial transplant sutured in place (Phemister, Annals of Surgery, December, 1915).

Ununited fractures of the patella, *i. e.*, old fractures of the patella, have been treated successfully by Phemister (1915), Gallie (1923), by the use of transplanted fascial flaps and by the use of transplanted fascial strips of fascia lata.

The advantage of using full fascial transplants is that they afford a stronger closure of the defect than can be obtained by taking flaps from the weaker surrounding fascia, and in no way weakens any of the normal portions of the extension apparatus. The transplant should be made wide enough to cover the defect in the lateral ligaments of the patella as well as

Fig. 1541.—Amount of extension six months after operation (Phemister, Annals of Surgery, December, 1915).

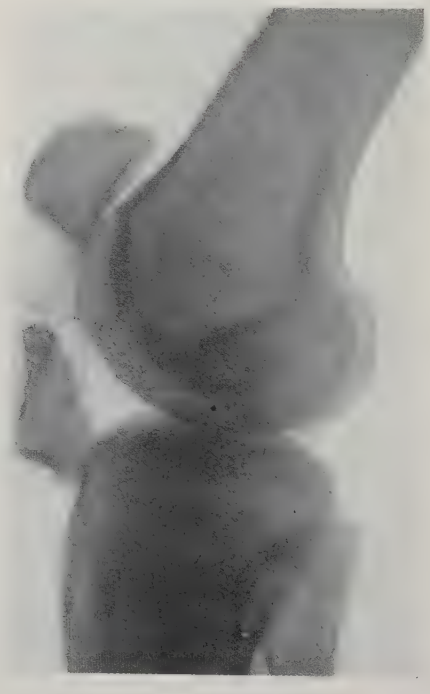


Fig. 1542.—Roentgenogram six months after operation (Phemister, Annals of Surgery, December, 1915).

that between the fragments. See Figs. 1538–1542 of Phemister's successful case, following the above procedure.

FREEMAN'S BONE-CLAMP

Freeman's instrument for extension in leg fractures. Ordinarily, in fracture of the tibia and fibula, if traction will not reduce the displacement, an open operation is the quickest, safest, and most effective procedure. Freeman has devised and used successfully the best thus far produced of the external bone clamps. It may serve a useful purpose. It resembles the original Lambotte instrument. I therefore reproduce its essential features. I quote Freeman's description:

Technic.—The instruments required (Figs. 1543–1547) are: (1) Several

strong, steel bone-screws, about $2\frac{1}{2}$ to 3 inches in length and $\frac{3}{16}$ inch in diameter. (2) A drill making a hole slightly smaller than the screws (ordinary machine twist-drills are the most suitable). (3) A properly constructed turnbuckle. (4) A long clamp for holding the screws in position after adjusting the fracture.[1]

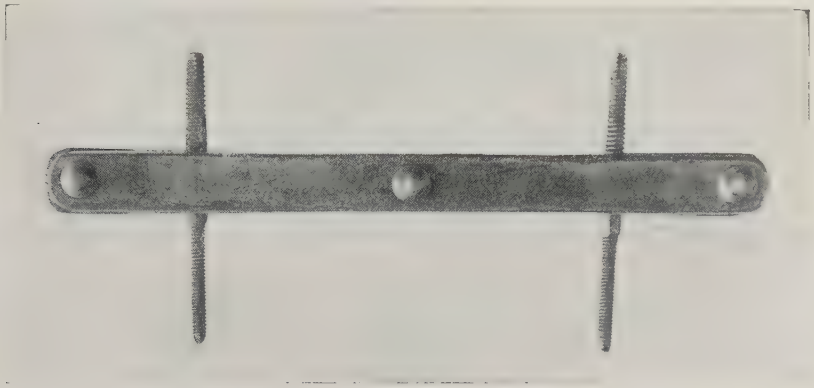


Fig. 1543.—Side view of bone-clamp.

The operative steps are:

1. Obtain an *x*-ray picture of the break, noting the amount of overlapping of the fragments.

2. Prepare the skin as in any other operation.

3. Under general anesthesia adjust the fragments roughly, especially as regards rotation, being careful that the inner border of the foot is on a line with the inner border of the patella.

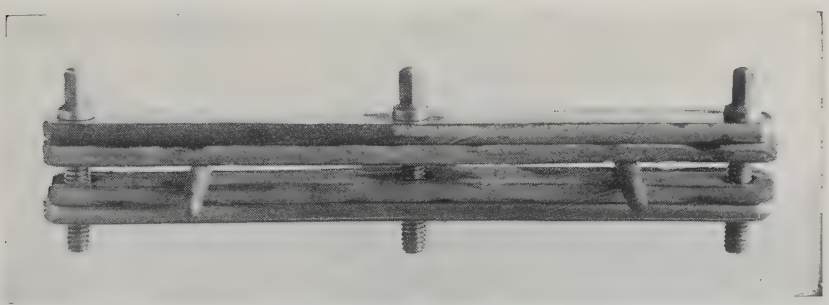


Fig. 1544.—Top view of bone-clamp, showing lining of soft wood in which the bone-screws become firmly embedded when the clamp is tightened.

4. With a sharp-pointed knife make two small, buttonhole incisions over the center of the flat surface of the tibia, one on either side of the break and at some distance from it. They should be just large enough easily to admit the drill and should reach to the bone.

[1] These instruments can be obtained from W. H. Lauth, 1632 Court Place, Denver, Colorado.

5. Insinuate the drill through the soft parts and bore clear through the medullary cavity, so that the instrument obtains a firm hold in the posterior osseous layer.

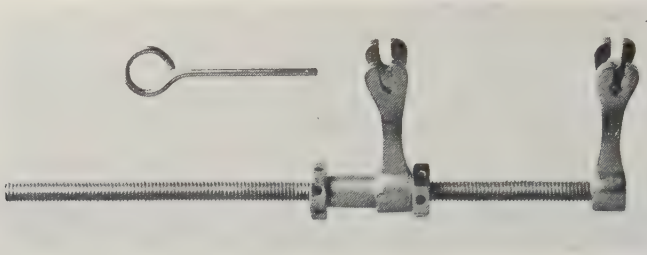


Fig. 1545.—Turnbuckle. The distal nut is for the purpose of loosening the sliding arm if it should catch.

6. Remove the drill and replace it with a bone-screw, which gets a firm fixation because it is slightly larger than the drill and penetrates both sides of the bone.

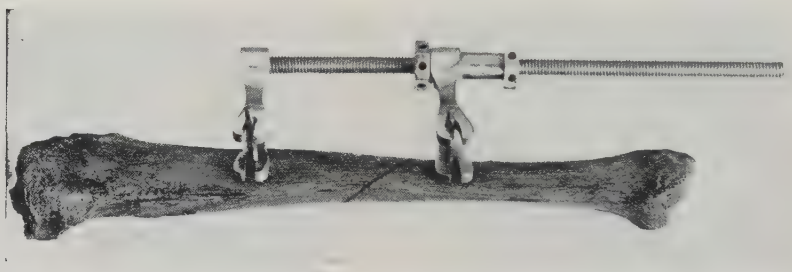


Fig. 1546.—Turnbuckle in position for applying extension.

7. When the screws have been placed, one above and one below the fracture, insert the turnbuckle between them, close to the skin (Fig. 1546),

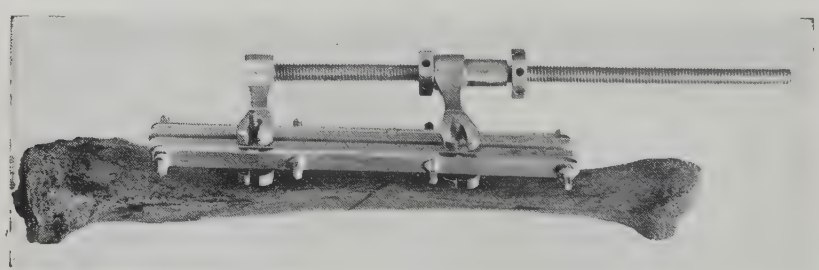


Fig. 1547.—Bone-clamp in place preparatory to removal of turnbuckle.

and apply extension, corresponding in degree to the overriding of the fragments, previously noted by the *x*-ray, or by measurement of the opposite

limb. When possible the progress of the adjustment may be observed through a fluoroscope.

8. Place the clamp upon the screws as low down as practicable in order to reduce the leverage, thus maintaining the extension (Fig. 1547), after which remove the turnbuckle. If either fragment tends to project forward beneath the skin it should be pressed into place before adjusting the clamp.

9. Apply dressings and a bandage. If only two screws have been used, a light splint may be desirable to maintain the general alignment of the limb.

The after-treatment consists in changing the dressings every few days and painting the skin around the screw-holes with 2 per cent. tincture of iodin.

When removal of the apparatus is decided upon, it is easily accomplished by taking off the clamp and unscrewing the screws from the bone. No anesthetic is required, as but little pain is produced, or none at all. The holes are then painted over with tincture of iodin and usually heal in a few days. A splint or a light plaster-of-Paris splint may be applied until consolidation is complete.

If one wishes, two screws can be inserted on each side of the fracture instead of one, thus gaining additional firmness, but this seems hardly necessary in the majority of instances.

THE OPERATIVE TREATMENT OF OLD POTT'S FRACTURES

The exact indications for operation in old deforming Pott's fracture will be persisting lateral or backward displacements. The only method for the relief of these deformities is by osteotomy of the tibia and fibula. The results following this operation are satisfactory.

In old ankle-joint fractures with certain positive disabilities the symptoms are very disabling, manual force is unable to replace the fragments, recourse must be had to the Thomas wrench or the Gwilym Davis lever (see p. 681). As has already been suggested, a tenotomy of the tendo achillis may be helpful.

At Operation for Old Ankle Fracture.—If reposition is impossible, operative reduction must be done.

In this operation (Ashhurst) a liberal incision is made around the anterior and lower border of each malleolus; the skin and superficial fascia are reflected backward until the fractured surfaces are exposed; these will include the internal malleolus and the fibula, as well as the inferior tibiofibular joint. Interposed edges of fascia and periosteum are raised from the fractured surfaces, which are freshened with a curet; the tendon of the tibialis posticus and, if necessary, those of the peronei are temporarily removed from their grooves, the fracture is accurately reduced, and the fragments temporarily held in apposition by one of Lambotte's large clamps, while his self-boring screws are being inserted or, preferably, Sherman screws. The tendons being replaced and the deep fascia and skin sutured, a dressing is applied and the fracture is treated as a recent simple closed fracture, except that protection

by gypsum splints is not required for more than a couple of weeks. Weight bearing, however, cannot be resumed any sooner than in cases in which open reduction has not been done (Ashhurst).

The Operative Treatment of Old Fractures of the Leg Near the Ankle.—The indications for treatment of old deforming fracture, whether following fracture of the lower epiphysis of the tibia, Pott's fracture, or fracture of the tibia and fibula just above the ankle, are the same—the re-establishing the

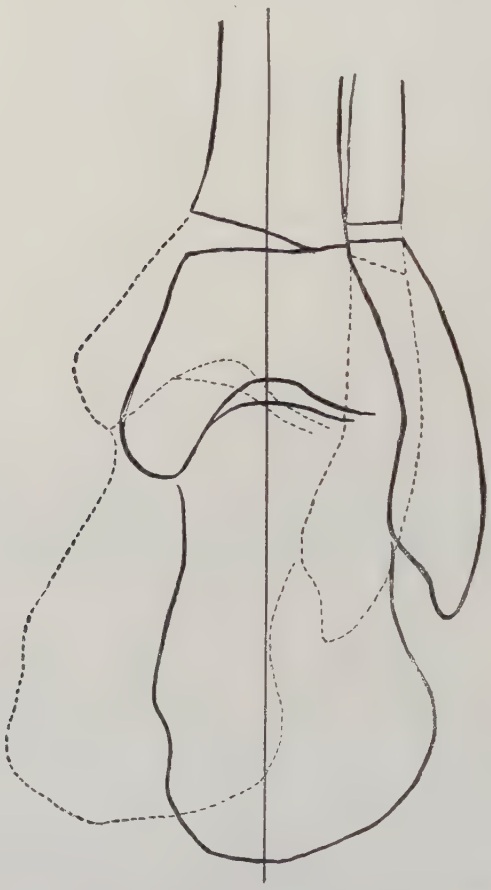


Fig. 1548.—Diagram showing operative lines of osteotomy to correct old deformity (Feiss).

proper weight-bearing line. It is important to eliminate from the problem the compensatory functional deformity.

The following case (Feiss) is cited to illustrate the method of procedure applicable to many of these cases:

Figure 1294 shows the position of the ankle and foot due to damage to the epiphysis of the lower end of the tibia. Figure 1295 shows the real deformity upon putting the foot in a position of rest. Figure 1296 shows the *x*-ray illustrating the abnormal growth of the bones.

By an osteotomy of the tibia and resection of a piece from the fibula, as planned in Fig. 1548, it was possible to correct the static deformity, with the result seen in Fig. 1549.

Fig. 1549.—Casts showing appearance of ankle before and after operation (Feiss).

Bone grafting of the mandible is well described by Billington and Round. Crest of ilium grafts are employed held by dental splints until the soft parts are healed. Final adjustments made when bony union is partial.

[1] British Journal of Surgery, January, 1926, p. 497, vol. xiii, No. 51

CHAPTER XXVI

FRACTURES LIKELY TO REQUIRE OPERATION

It remains summarily to state the fractures which in my experience and in the experience of other surgeons at times have needed operative treatment. It is distinctly understood that in such an enumeration the conditions cannot be covered which might lead to the operative treatment (see references to individual fractures). All the available facts of each case are to be carefully weighed. This summary, of course, does not include compound fracture, ununited fracture, or malunited fracture with symptoms.

Depressed Fracture of the Skull With or Without Symptoms.—Injury to the head with rising intracranial pressure demands operation (see p. 45).

Compression Fracture of the Spine.—(See p. 141.)

Fracture of the Body of a Vertebra Without Cord Symptoms.—It is highly improbable that an arthrodesis of the spine by bone-grafting, splinting above and below the injury, will become a routine procedure. The value of such procedure is still in the experimental stage (see p. 143).

Depressed Fracture of the Nose.—This depression may usually be reached from within the nose (see p. 66).

Fracture of the Malar Bones.—(See p. 69.)

Fracture of the Maxilla and Mandible.—Very rarely will operation through a skin incision be required (see p. 105).

Fracture of the Clavicle.—The recumbent dorsal position is so effective that rarely will operation be required in a recent fracture.

Fractures of the Upper End of the Humerus.—If the greater tuberosity is much displaced it should be operated on. Fracture of the surgical neck not corrected by position and immediate traction should be operated upon. A small incision and digital reduction by leverage may be effective. Certain transverse fractures and all fractures which cannot be reduced in active adults should be operated on. Fracture with dislocation of the humeral head will need operation (see p. 266). Separation of the upper humeral epiphysis may require exact reposition.

Fractures of the Shaft of the Humerus.—If there is doubt about union occurring, if there is probable soft part interposition, operation should be done early rather than late. Early operation will find a more normal bone to deal with than if one delays operation.

Fractures of the Lower End of the Humerus.—Fractures of the external condyle with irreducible displacement of the fragment will always require operative reduction. Transverse, supracondylar, and diacondylar fractures and those injuries commonly classified as separation of the lower humeral epiphysis if irreducible should be replaced by an incision and direct manipulation and leverage. Absolutely perfect reduction of all joint fractures includ-

ing the elbow is desirable. Immediate postoperative active movement should follow. Certain uncomplicated fractures entering the joint surfaces in adults should be operated at the outset (see p. 349).

Fracture of the Olecranon.—Where perfect power and complete function of the elbow are to be sought, operative suture is often necessary (see p. 835).

Fracture of the Upper End of the Radius.—Operation: Displaced fragments of the head and neck should be removed early after the injury.

Fracture of Both Bones of the Forearm.—Complicated displacements of the four ends of the fragments will almost always require early replacement by operation (see Figs. 1559–1562) in adults, in children rarely.

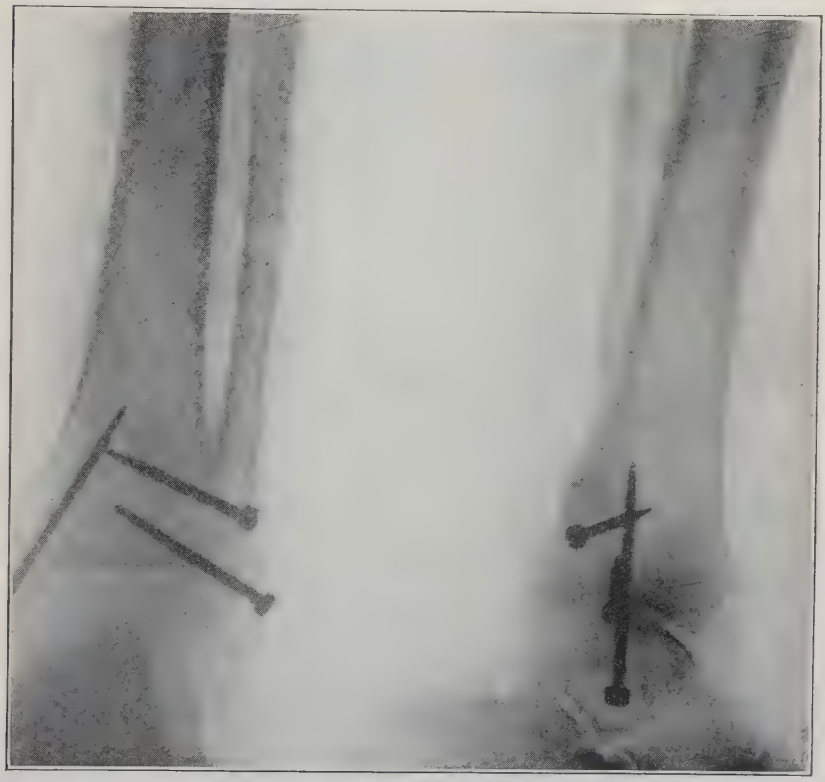


Fig. 1550.—Ankle fracture, two attempts at reduction unsuccessful. Result of arthrotomy and screw fixation seen eleven days after the injury. Out of work thirteen weeks. Perfect anatomical and functional results. The Lambotte screws are in place and causing no disturbance seven years after the operation (Ashhurst, Oxford University Press).

Fracture of the Carpus.—Operation in recent cases will occasionally be necessary.

Fracture of the Metacarpal Bones.—It may be desirable to operate in recent cases.

Fracture of the Radial or Ulnar Shaft Alone.—Fracture of the shaft of either the radius or the ulna will often require reposition through an incision.

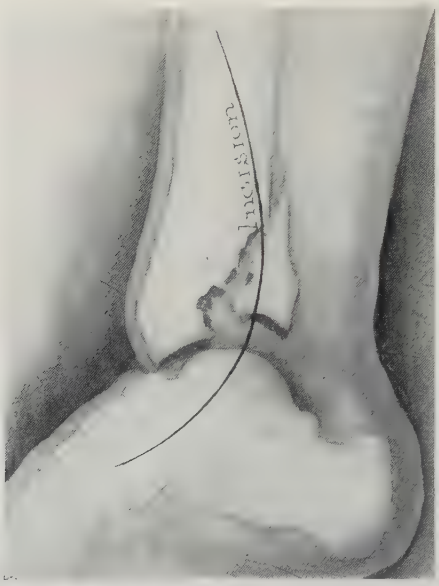


Fig. 1551.—Diagram of fracture of lower articular posterior margin of tibia with displacement backward of the astragalus and foot. Note the line of incision in approaching the fracture (Lounsbury and Metz).

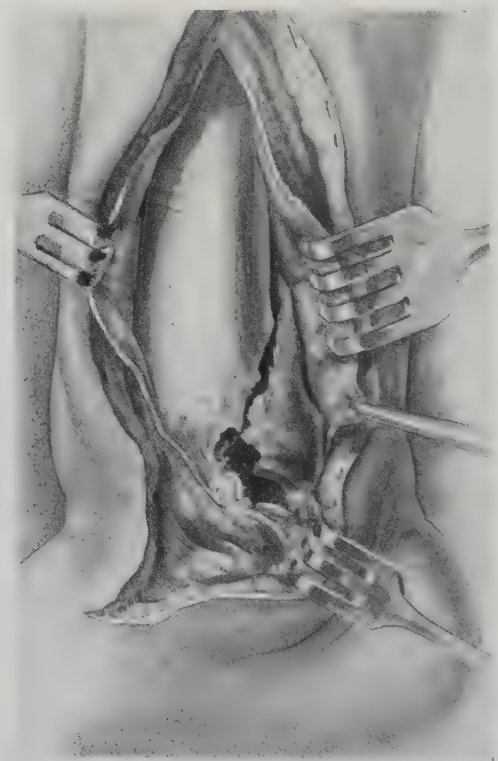


Fig. 1552.—Drawing illustrating fracture of the posterior edge of the lower tibial articular surface. Note exposure of the fracture and the adjoining shaft (Lounsbury and Metz).

Elbow Fractures, T and Y.—Cases in which manipulation and position do not effect reduction should be operated upon.

Fracture of Neck of the Femur.—Few recent cases should be operated on.

Displacement of the Upper Epiphysis of the Femur.—Occasionally operation will be required.

Fracture of the Shaft of the Femur.—Fractures in adults which cannot be reduced by an anesthetic and manipulation and traction and adequately held reduced, should be operated on.

Fractures of the upper third and the lower third of the shaft will often demand operation. A stout individual with fracture at the junction of the upper and middle thirds can be handled most satisfactorily by operation.

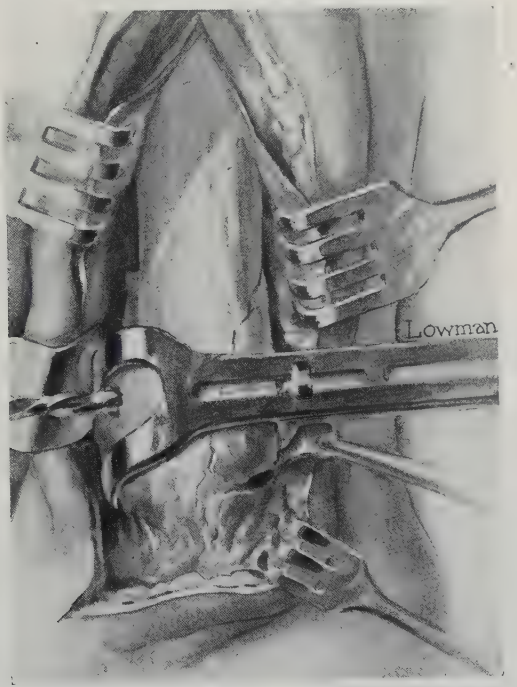


Fig. 1553.—Drawing illustrating use of the Lowman clamp in holding the fragments, seen in Fig. 1552, in close approximation, while the appropriate sized screw hole is being made by the drill (Lounsbury and Metz).

Separation of the Lower Femoral Epiphysis.—When bloodless reduction fails, operation will be necessary.

Fracture of the Patella.—With separation of one-half inch or more should be operated on (see p. 863).

Fracture of the Bones of the Leg.—Fractures with marked displacement in which skeletal traction does not satisfactorily reduce the fragments should be operated upon. Posterior and anterior "lipping" fractures that cannot be suitably held by non-operative means should be operated on (Fig. 1551). Many oblique tibial fractures should be operated, for fibrous union does often occur and a perfect early operative reduction will give the greatest likelihood of bony

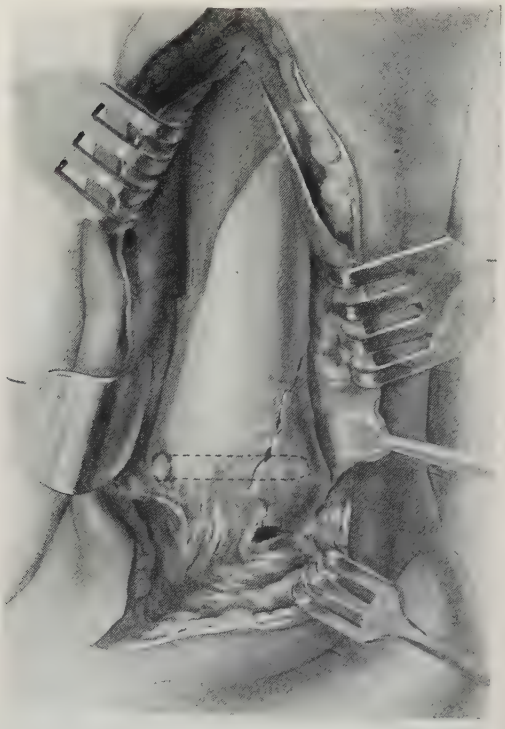


Fig. 1554.—Drawing illustrating completion of the operation upon the bone. Note the bone peg driven into screw hole holding fragments together. The peg has been cut flush with the tibia (Lounsbury and Metz).

Fig. 1555.—Fracture of the lower end of the tibia and of the fibula. Lateral view (Lounsbury and Metz).

Fig. 1556.—Same as Fig. 1555, anteroposterior view (Lounsbury and Metz).

Fig. 1557.—Same case as Fig. 1555 after operation by heterogeneous bone peg. Note bone peg *in situ* and general alignment (Lounsbury and Metz).

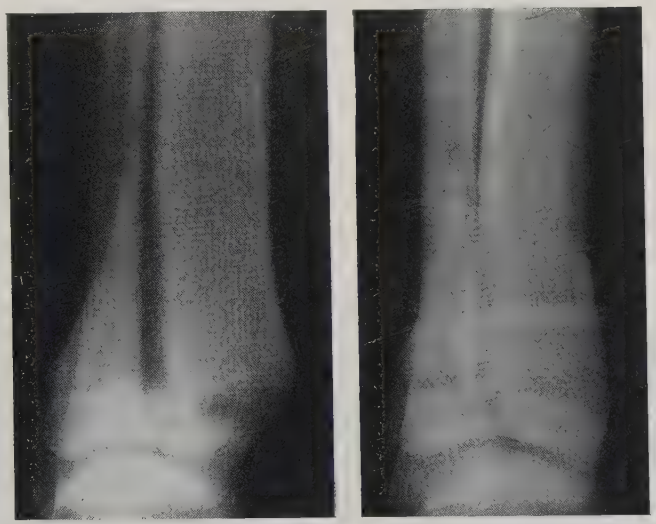


Fig. 1558.—Case of a girl sixteen years old. Epiphyseal separation and fracture of the lower end of the tibia. Three weeks following the injury, see adjoining cut, replacement of fragments by operation, the fragments were held by a bone peg (Lounsbury and Metz).

union. Early operation in these cases means early accomplishment of function.

Fracture of the Ankle.—Fractures entering the ankle-joint in young, active adults, which cannot be replaced and held replaced, demand operation (see Figs. 1550–1552).

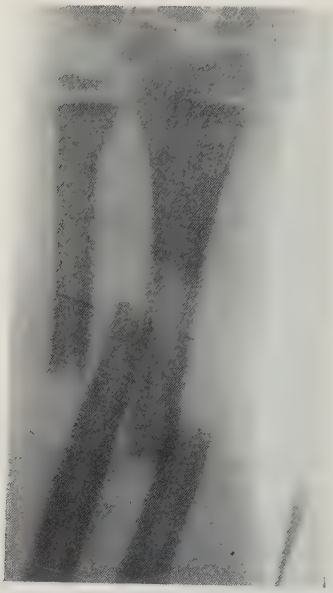


Fig. 1559.—Anteroposterior view of fracture of both bones of the forearm in a child of seven years. Note overriding and lateral displacements and angulation. A type of fracture wisely treated by operation.

Fig. 1560.—Lateral view of same case as Fig. 1559. Note anteroposterior displacements and overriding.

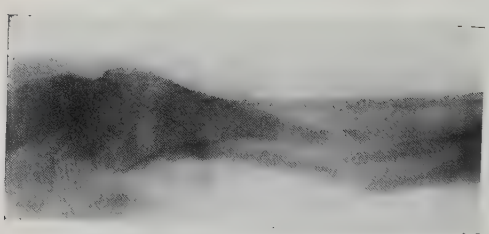


Fig. 1561.—Same as Fig. 1560. Lateral view, showing that, although the lateral displacement is eliminated, there is remaining an anterior bending of the shaft of the radius. This might have been corrected completely had the *x*-ray record been made immediately following the operative replacement.

Fig. 1562.—Roentgenogram of fracture of radial shaft with considerable shortening and consequent overlap of radial fragments. Treatment by open reduction, no internal retentive splint. The above is the result anatomically.

Fracture of the Os Calcis.—If the line of fracture enters the astragalar-calcaneal joint an immediate restoration of the foot to its best position and an arthrodesis of the joint is wise treatment (Allison, Wilson).

The Cotton, Hall, Magnuson, and Straus maneuvers are valuable.

CHAPTER XXVII

COMPOUND OR OPEN FRACTURE

The problems confronting the surgeon in the care of a fracture which communicates through the damaged soft parts with the external surface of the body are always difficult.

The open fracture may be considered under five headings:

A. Emergency treatment.
B. The treatment of shock.
C. General considerations.
D. The damage to the soft parts.
E. Treatment of the compound fracture.

A. EMERGENCY TREATMENT

The injured person should be placed and kept in a horizontal position and not permitted to sit up.

Morphin, if readily available, should be given subcutaneously to relieve pain absolutely and to avoid further shock. Large doses may be necessary. The patient should be kept warm. Extra coats or blankets should surround the patient. Hot coffee or tea or water may be given. Aromatic spirits of ammonia, 10 drops, and repeated after twenty minutes for two or three doses, may be helpful. A tourniquet around the injured limb will only be needed if there is much continuous bleeding. The tourniquet will often do harm to the region of the fracture unless it is placed carefully.

Temporary Dressing.—The immediate treatment should be directed to the prevention of any further injury, *i. e.*, mechanical or by infection.

In the absence of sterile gauze, a sterile or laundry clean handkerchief or strips of clean bed linen or the equivalent should be applied over the wound. This dressing should be applied loosely without constriction. No attempt at reduction of the fragments of bone, even though they appear in the wound, should be made until the injured man reaches a hospital. In fact, every precaution should be taken to prevent any protruding bone from receding into the superficial wound. Further dissemination of infection will thus be avoided. Operation under an anesthetic is necessary to thoroughly cleanse the wound. No antiseptic should be injected into the wound.

The most effective method of immobilizing and transporting a fracture of the upper or lower extremity is by means of the Thomas splint (see p. 536). Every practitioner of medicine and surgery, if likely to be called to a fracture, should be provided with a Thomas arm and Thomas leg splint. Every practitioner should know how to effectively use these two splints (see p. 539).

The limb should be held still, fixed to some sort of a splint. If a Thomas splint is not to be had, the arm may be held against the body by a towel

swathe. The leg may be held against the opposite leg by a towel swathe. Either limb may be immobilized without undue constriction by placing it against a padded (with a folded coat) splint made of narrow boards or sticks, holding it in contact by towels. The injured individual should be transported to the nearest hospital as quickly as possible.

B. SHOCK

The patient should not be washed or in any way disturbed.

The shock attending an open fracture is generally greater than that following a closed fracture. A degree of shock requiring vigorous treatment is not always present. As has been indicated, heat should be applied to the body. If it can be determined that there has been great loss of blood, a blood-transfusion may be indicated. If active hemorrhage is an important factor in this shock, of course, bleeding should be stopped at the beginning of treatment.

If very great shock is manifest, or if there is great pain, an adequate amount of morphin should be given subcutaneously. Absolute quiet should be provided. Salt solution given slowly subpectorally, 1 or 2 pints, is helpful. Sodium bicarbonate should be added to the salt solution. If the shock is apparently serious, to the subpectoral salt solution may be added 10 or 15 minims of adrenalin chlorid solution, 1 : 1000.

If there is very profound shock the injured man will look it. He is utterly relaxed; pale as the dead; his eyes are pallid and sunken, he is apparently but not really unconscious; his breathing is shallow and frequent; his heart-beat rapid and feeble; his pulse is scarcely to be felt at the wrist, and when the diastolic arterial pressure is taken it is found to be dangerously low, 60 mm. or thereabouts (W. T. Porter).

C. GENERAL CONSIDERATIONS

There should be no unnecessary moving of the patient. Moving and transporting a patient with fracture materially increases shock and pain and tends to spread infection if it is present.

Roentgen-ray Examination.—The patient should be received at the hospital on a table or truck capable of affording an *x*-ray examination without disturbing the fracture. The *x*-ray should be taken as soon as practicable, and, if possible, should be taken without moving the patient from the table or truck on which he is first placed. This *x*-ray will give immediate information of the location and extent of the bone lesion.

Further examination should determine:

(1) The location of the wound or wounds; their size and appearance.
(2) The extent of damage to the soft parts of the limb.
(3) The extent of important blood-vessel and nerve injury.
(4) The extent of damage to adjacent parts.
(5) Associated injuries in other parts of the body; possibly damage to neighboring joints.

D. DAMAGE TO THE SOFT PARTS

The Possibilities of Infection.—The time elapsed since the accident will be a valuable guide as to whether an infection is present or not in the wound.

It will be important to determine the nature of the accident—whether the limb was run over by a cartwheel, crushed by a heavy weight, or whether the man fell and the bone wounded the skin from within out. If the accident was a crush (direct violence) the damage to the soft parts may be considerable. And if the accident was due to indirect violence the soft part damage will be much less.

The likelihood of infection at the beginning, that is, at the time of the accident, will somewhat depend upon whether the infection has been introduced from without and rubbed into the wound. A *culture* should be taken from the wound before any antiseptic has been used.

The damage to the soft parts may occur at a different level from the injury to the bone. It may be impossible to tell by inspection whether the superficial wound communicates with the fracture or not.

Just as it is often difficult to know whether a stab or pistol-wound of the abdominal wall has entered the peritoneal cavity, so it may be as difficult to tell the relationship of the superficial skin wound and that of deeper parts. Any fracture associated with a superficial skin wound should be assumed to be an open fracture and should be treated at the outset accordingly until it is proved to be otherwise.

A wound from within out is presumably associated with only a mild infection. If the appearance of the parts is grossly clean and if the kind of injury and the local appearances suggest strongly that the wound of the soft parts happened after the bone was broken, by penetration of the soft parts by a fragment of bone, a mild infection may be present.

A wound from without in. If, on the contrary, the kind of injury, a rolling or crushing accident, and the local appearance of the skin and the feel of the part involved suggest that the damage to the bone occurred after or at the same time as the damage to the soft parts, the fracture is presumably associated with extensive laceration of tissue and with a beginning infection which will become serious unless adequate treatment is instituted early.

In other words, an infection of an open fracture will be either entirely absent, mild, or severe from the outset.

These degrees of infection will depend:

(*a*) On the exact bacteria concerned.

(*b*) The associated damage to the soft parts—whether the wound of the soft parts is from within out or from without in.

(*c*) The length of time which has been allowed to elapse before antiseptic treatment is instituted.

In civil practice, open fractures, in which the wound is small and probably caused by the broken bone protruding out through a tiny wound of the skin, are ordinarily not infected. About 75 per cent. of such wounds heal immediately with no sign of subsequent infection. But the very important fact remains that even granting the foregoing to be absolutely true, the sur-

geon confronted with an open fracture can never be absolutely sure that it is not infected. A wound apparently simple and made from within outward may have had ground into it septic material from the outside. A wound apparently simple may have become infected by a once protruding bone fragment, which after having been soiled and impregnated with bacteria, oil, and dirt, retracted and was withdrawn into the deep wound carrying virulent infecting material with it. Moreover, the tiny skin wound may deceive the surgeon, for there may be associated with the small superficial skin wound complicated and extensive wounds of the underlying and adjacent soft parts.

Therefore, the fundamental basis for the treatment of open fractures is that all open fractures are potentially infected.

A closed fracture may become an open one:

(*a*) The skin may be so contused that it subsequently sloughs and leaves an open wound to the fracture site.

(*b*) Blebs filled with serum or blood may form in the skin about a fracture and become septic and lead to serious infection (see p. 925).

(*c*) The delirious patient may cause a closed fracture to become an open one by restrained or unrestrained moving about in the bed.

(*d*) A fragment of bone may press so hard against the skin from within that a necrosis of the skin may result. The bone may protrude through the skin. This secondary wound may become septic and cause serious mischief.

(*e*) So great a hemorrhage may occur associated with laceration of blood-vessels and muscle tissue that the tension on the surface skin may require incision to relieve the circulation of the limb. Such a forced procedure makes the closed fracture a secondarily open one, but, of course, under the control of the surgeon, and presumably it will remain clean.

E. TREATMENT OF THE COMPOUND FRACTURE

General Remarks.—A compound fracture being a fracture with infection (presumably), if the bone becomes infected necrosis of bone may occur, sequestra may form. Consequently, the reparative process will be occupied in a compound fracture with three things: 1, fighting and eliminating any local infection; 2, eliminating necrotic bone; 3, healing the original fracture.

The first object of local treatment of an open fracture wound is to free the damaged parts not only of bacteria, but of all pabulum favorable to their growth, namely, foreign bodies, blood-clot, tissue partly or completely devitalized.

The earlier and more thoroughly this is carried out, the better. The more virulent the original infection and the longer the delay in cleansing the wound, the less surety is there of a successful outcome.

The second object after sterilization of the wound is the facilitating proper repair of all tissues, soft and hard, that is, suture and closure in whole or in

part of the soft wound, and correction of displaced bone fragments by mechanical means. Compound or open wounds will vary in extent and severity and in the degree of infection.

A tourniquet should very rarely be necessary in case of open fracture. Unless it is applied very exactly it is liable to cause serious damage to the soft parts and to the seat of fracture. It will be always unwise to attempt immediate closure of the open wound if more than ten hours have elapsed since its origin, and only then if the infection is probably mild.

The care of a compound fracture will be described under the following heads:

The employment of antitetanic serum.
The sterilization of the skin.
The mechanical cleansing of soft parts and bone.
The chemical sterilization of soft parts and bone.
The treatment of the fractured bone:
  By suspension.
  By reposition.
  By traction.
  By direct fixation.
The treatment of the wound of the soft parts:
  By passive healing.
  By secondary suture.
  By primary suture.
The Carrel-Dakin Method.

Antitetanic Serum.—The administration of a prophylactic dose of antitetanic serum will be necessary in wounds predisposed to infection with the bacillus tetani—such as wounds caused by street accidents and accidents in stables. I believe it is a wise precaution to be used in all badly lacerated wounds.

The dose for prophylactic injections for an adult is 1500 units. This should be given intramuscularly either into the thigh or the abdominal wall muscles. This prophylactic dose should be repeated in eight to ten days and again in sixteen to twenty days. The immediate administration of tetanus antitoxin is more effective than a late dose. Give antitoxin at once after the injury.

The repetition of the original dose should be unnecessary unless there is a strong suspicion that the wound has been contaminated by tetanus-bearing soil.

The taking of specimens for culture: Specimens should be taken both for direct examination by smears and for culture.

If any sign of tetanus appears in a given case the wound should be laid widely open, every part of it cleaned and drained, and peroxid of hydrogen freely used in the wound. Large doses (50,000 units) of antitoxin should be given subcutaneously, intramuscularly, and intrathecally.

In the treatment of a developed case of tetanus, the following general principles should be carried out:

1. The primary focus of infection (in a compound fracture, the wound) should be laid wide open, thoroughly débrided, and left open. The condition of the fracture becomes, in the presence of tetanus, of secondary importance. The wound should be very lightly packed with gauze saturated with hydrogen peroxid, and this should be changed every hour. The dressing must not be bandaged on; the wound should be, save for the above-mentioned packing, open to the air.

2. The patient should be in a darkened room, with the best available special nurses. Various sedatives may be employed—morphin, bromids, paraldehyd, etc.; or, in convulsions, ether. I believe that luminal, in doses of from 1½ to 3 grains every three hours, is of value. Feeding will have to be carried out according to the patient's ability to take food. If it can be given by mouth, well and good; if not, recourse may be had to feeding through a nasal tube; to rectal, intravenous, and subpectoral alimentation.

3. The use of antitoxin:

(*a*) At entrance inject 1500 units around the wound, 30,000 units intravenously, and 10,000 units intraspinally.

(*b*) In twelve hours repeat the 30,000 units intravenously.

(*c*) In twenty-four hours repeat *a*.

(*d*) In thirty-six hours repeat *b*.

This will total 143,000 units in the first forty-eight hours. From now on the dosage will depend on the patient's condition. The intravenous and intraspinal injections should be given under a general anesthetic. The doses for small children may be a little less than the above, but not very much less (Richard Miller).

Sterilization of the Surrounding Skin.—It is very important during the skin sterilization that further infection is not carried into the wound from without. The cleansing should be carried on centrifugally from the wound, not toward it.

The skin should be washed with sterile green soap and water, shaved, washed carefully with alcohol, 70 per cent., and then washed with benzene.

In case the skin is soiled by grease and oil, I find that this is most easily removed by the use of liquor sodæ chlorinatæ (chlorinated soda) about 1 part to 30 of water. This seems to cut the grease and facilitate skin cleansing.

This preparation is followed by thoroughly covering the skin with tincture of iodin, full strength, or by a 5 per cent. picric acid in alcohol (Beekman) or by Harrington's solution (acid bichlorid solution).

Harrington's solution is composed of:

Corrosive sublimate	1.5 gram
Hydrochloric acid	100 c.c.
Glycerin	100 c.c.
Alcohol (95 per cent.)	1200 c.c.
Distilled water	2000 c.c.

I personally use the tincture of iodin for final skin sterilization.

I take the precaution after operation to wash away all the tincture of iodin—easily removable by bathing the skin with alcohol, 70 per cent. Thus will be avoided the irritation from the iodin of sensitive skins. The sensitiveness to iodin is not often found. If it does exist, however, it is especially distressing to patient and surgeon.

The Extent of Sterilization of the Skin.—In the limbs the sterile preparation of the skin should extend to include the joint above and below the seat of the fracture, thus is ensured a wide sterilization.

A foot and ankle or a hand and wrist, if not needed in the operative field, should be covered respectively by special Canton flannel, sterile, loose socks tied on, and by gloves so fastened that they are not readily dislodged in the subsequent manipulations necessarily attending operation.

The Mechanical Cleansing of the Wound.—*First Step.*—If the wound is associated with severely lacerated tissues, this consists in:

(1) The removal of all blood-clot and foreign material (clothing, etc.).
(2) The excision of ragged, bruised, or devitalized skin edges.
(3) The excision of dead muscle, strips of fasciæ, edges of ligaments, etc., etc.
(4) The removal of bits of bone that are entirely separated and loose and free from all tissue connection.

The dirtier the wound, the more thorough must be this step. At the conclusion of this step the wound should be thoroughly flushed with sterile warm salt solution. All this mechanical cleansing resulting in a relatively clean wound is done with one set of instruments.

Second Step.—This should be done with fresh sterile instruments unused in the previous step.

(1) The surrounding skin should again be chemically sterilized.
(2) The edges of the wound should be protected by freshly applied sterile towels held by numerous towel clips.
(3) If a tourniquet was used for the first cleansing, it should now be removed and all bleeding vessels ligated with fine chromic catgut.

Chemical Sterilization of the Wound Already Made Grossly Clean.—If the wound is obviously dirty, it should be cleansed by means of small swabs of gauze dipped in green soap, and the entire wound should be washed with benzene, followed by alcohol, and finally by ether. A wound thus carefully cleansed step by step in every nook and cranny will be as nearly sterile as it is possible to make it.

Cleansing of the Fractured Bone Fragments.—*Mechanical Cleaning.*—Scrubbing of the bone with a sterile nail-brush and green soap is to be followed by the use of bone forceps or rongeurs and a curet in order to thoroughly free the bone of the gross dirt ground into its fibrous covering and even into the very bone itself.

Chemical Cleansing.—After the use of green soap with the soft part wound protected, the bone may be sterilized by swabbing carefully with alcohol, 70 per cent., followed by ether. The materials employed in the sterilization of the wound will vary with the surgeon's experience.

It may be necessary to cleanse the bone by use of the rongeurs and a curet so carefully as to completely freshen the bony surfaces.

Carrel Treatment.—The wound should be left wide open. The Carrel treatment should be installed at once. The Carrel tubes are placed in every pocket and cavity. Dakin's solution is thus permitted to flow every two hours freshly into every recess of the wound (see p. 899 for Carrel Treatment).

The Treatment of the Fracture:

(1) By suspension.
(2) By reposition.
(3) By traction.
(4) By direct fixation with or without traction.

All compound fractures should be treated by suspension, preferably in a Thomas splint or its equivalent.

(1) In a few cases the mere reposition of the displaced fragments will lock and hold the fracture reduced. These cases will be few in number.
(2) In most cases the fragments cannot be held by mere reposition and slight impaction.
(3) Traction applied to the (*a*) skin, or (*b*) skeletal traction, or
(4) The direct application of plate or screw, or nail or wire, will be needed to maintain reduction.

(*a*) If the soft part wound is so situated that adequate skin traction can be effectively used it may be employed.

(*b*) If the wound precludes the application of skin traction and the type of fracture cannot safely be intrusted to skin traction, then skeletal traction is the method of choice. Traction will be furnished by the use of a Steinman nail or caliper.

(5) Should the fracture be difficult to hold satisfactorily by either direct reposition and locking, or by skin traction or by skeletal traction, then direct non-absorbable plate fixation, etc., may be used.

Screws used in compound fractures should include the proximal cortex only. They should not transfix the bone (Sherman).

A compound fracture wound is not more liable to the spreading of infection because the bones are held in exact apposition by a steel plate and screw. Union will begin in the bone some time probably before the infection is completely controlled. The repair in the soft parts goes along, *pari passu*, with the repair in the bone. The plate will be exposed at the bottom of the wound in certain cases and the gross reparative process in the bone be in full view.

After the plate or direct fixation appliance (non-absorbable screw, nail, etc.) has served its purpose, it should be removed, that is, after four or five weeks following its insertion. It should be removed whether the soft tissue wound is completely healed or not.

The Closure of the Soft Tissue Wound.—The closure of the soft wound will depend on one thing only, that is, whether bacteriological examination proves it to be clinically sterile (see Carrel-Dakin Treatment, p. 899).

Wounds of the soft parts associated with fractures group themselves into three main groups:

(1) Small punctured wounds from within out obviously not infected seriously, coming to the surgeon before the lapse of ten hours.

(2) Wounds which probably are infected and which are associated with considerable laceration of soft parts.

(3) Obviously badly infected wounds which have remained over ten hours without adequate treatment.

Primary suture of a wound means its immediate closure after its débridement and sterilization. Delayed primary suture means the closure of a wound after it has been sterilized before granulation tissue has appeared in any amount. Secondary suture means closure of surfaces already granulating.

Fig. 1563.—Case of severe crush of left thigh. Compound comminuted fracture of the left femur. One-third of skin and fascia of thigh destroyed by the crushing injury. Operation. Bone plate to femur. One year later left lower extremity practically normal in joint movements and usefulness (Berg, Pittsburgh).

Fig. 1564.—Same case as Fig. 1563 showing the convalescent Thomas-like splint with a joint at the knee, allowing movement at the knee as indicated (Berg, Pittsburgh).

Primary closure may be used in Group 1, or such cases may be allowed to heal without direct suture of the soft parts.

Secondary closure of the wound is the method of choice in Groups 2 and 3. This may be accomplished by either adhesive strapping or suture.

There may be a few cases of compound fracture in which it will be wise after providing suspension in a Thomas splint and steadying traction of some sort, to delay the direct bone-plate fixation until the Carrel treatment has rendered the wound clinically sterile.

The **Carrel-Dakin treatment** of infected wounds is the most satisfactory method at the disposal of the surgeon.

The corollary to the sterilization of the wound is its closure, but a wound should never be closed without knowing what it contains.

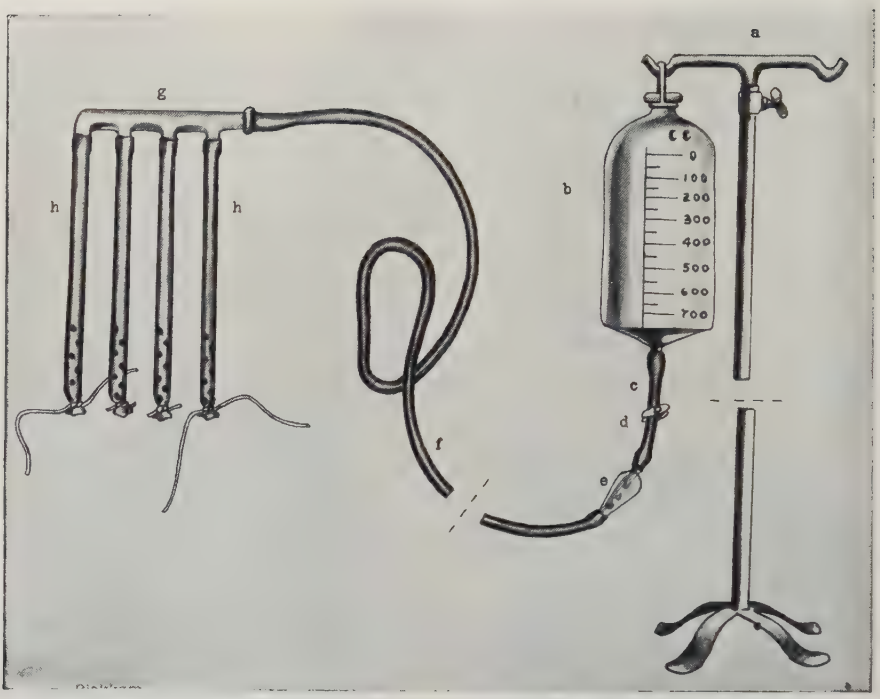


Fig. 1565.—The instrumental outfit for the application of the Carrel-Dakin technic in wound infection: *a*, Standard; *b*, reservoir for fluid; *c*, primary conducting tube; *d*, stop-cock, to control flow of fluid; *e*, glass connector, uniting primary and secondary tubes, and showing the rate of flow; *f*, secondary conducting tube, intervening between connector and distributor; *g*, glass distributor, or distributors; *h*, *h*, rubber distributing tubes, for delivering the fluid into the interstices of the wound—to the ends of some of which threads are tied for anchoring the tubes in the wound. (From Bickham, Operative Surgery, vol. i.)

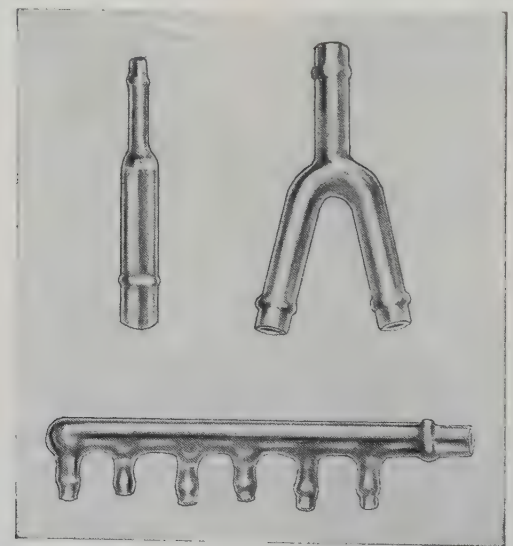


Fig. 1566.—Glass distributors: A, Single-way distributor (which should be shown with the smaller end downward, to be in conformity with the others); B, Y-shaped, or two-way distributor; C, six-way distributor. The Y-shaped distributor is here shown as used for interpolation between the rubber conducting tubes; if it is to be used in connection with the rubber distributing tubes the ends of the Y-piece should be smaller. (From Bickham, Operative Surgery, vol. i.)

Suture of a wound enclosing microbes may be followed by downright disaster. It is, therefore, only after having carefully looked into the bacteriological condition of a wound that one may bring its edges together by strapping or suture (Carrel and Dehelly).

The employment of the Carrel-Dakin method in a wound supplements the attempted mechanical operative instrumental débridement by a chemical débridement.

The Technic of the Carrel-Dakin Method of Sterilizing of Recently Infected Wounds.—This method aims at the chemical sterilization of the tissues. A chemical débridement of the wound by means of a continuous or frequently renewed application of Dakin's solution by means of specially prepared and specially arranged rubber tubes that supply every part of the surface of the wound with the antiseptic solution. The Dakin solution is a solvent of dead tissue.

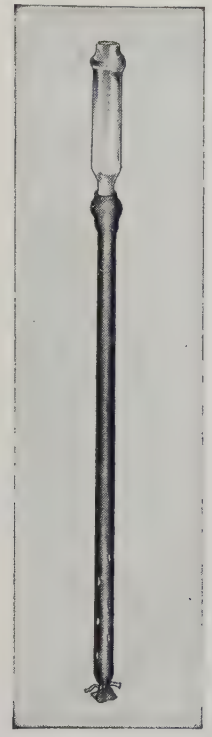


Fig. 1567.—Single-tube rubber instillating or distributing tube attached to a single-tube glass distributor, and tied at the distal end: the rubber tube is perforated in its lower part (from Bickham, Operative Surgery, vol. i).

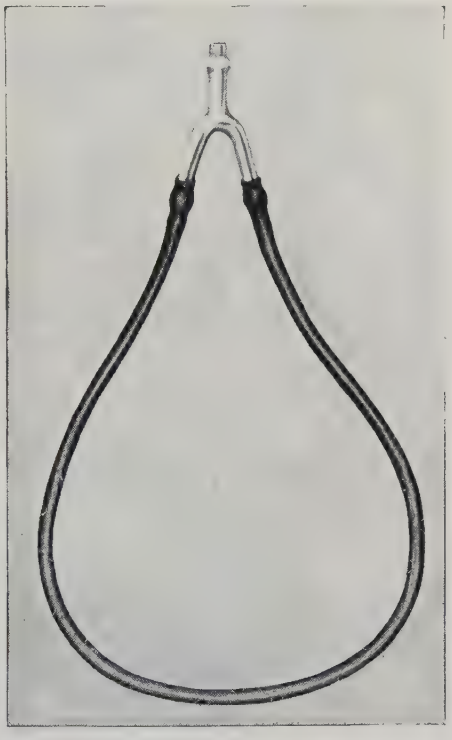


Fig. 1568.—Loop-distributor, or rubber instillation tube, attached to a Y-shaped glass distributor (from Bickham, Operative Surgery, vol. i).

Important in the use of this method are:

(1) The preparation of the Dakin solution or the selection of a previously prepared stable solution. The hyclorite made at the General Laboratories,

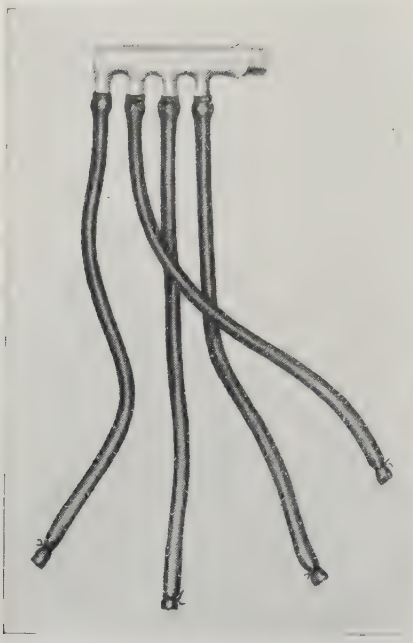


Fig. 1569.—Glass four-way distributor, to which four rubber distributing or instillation tubes are attached: The lower portions of the latter are perforated for the escape of fluid laterally, their ends being tied to prevent the rapid escape of fluid (from Bickham, Operative Surgery, vol. i).

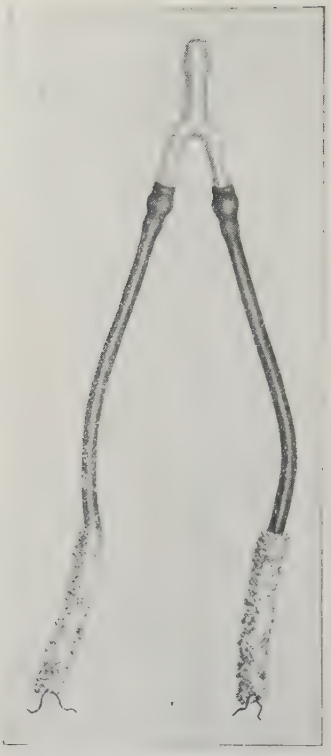


Fig. 1570.—Distributing tubes, connected with a Y-shaped distributor, above, and tipped with Turkish toweling, tied to their tips below (from Bickham, Operative Surgery, vol. i).

Fig. 1571.—Hand-flask for the Dakin solution—and pipet-syringe—for testing the perviousness of the individual distribution, or instillation tubes, before the wound is closed by dressing (from Bickham, Operative Surgery, vol. i).

Madison, Wisconsin is a stable solution from which Dakin solution may be safely and accurately made (see p. 904).

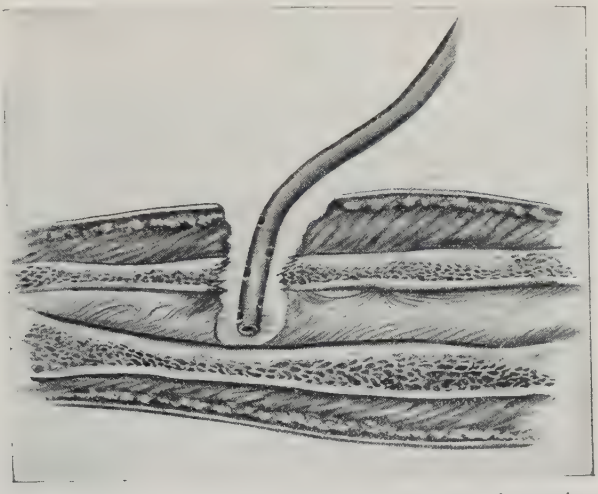


Fig. 1572.—Distributing tube in a wound with an upward opening, upon the anterior aspect of the body. The cup-shaped nature of such wounds mechanically holds the fluid in contact with the wound surfaces and recesses (from Bickham, Operative Surgery, vol. i).

(2) The arrangement of the Carrel tubes, which will ensure a flooding of all parts of the wound surface with the fluid. The ends of the tubes should be higher in all instances than the low point in the wound.

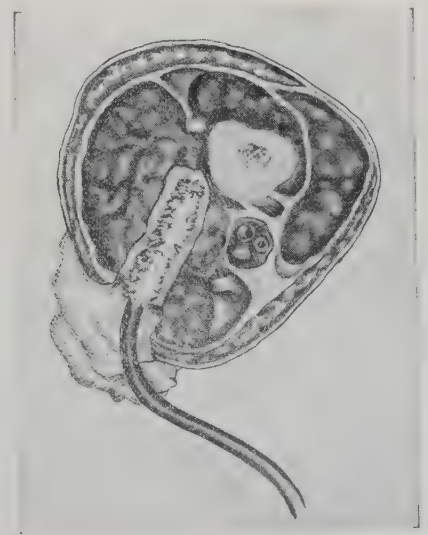


Fig. 1573.—Towel-covered end of distributing tube in a wound with downward opening—the outflow (and consequent ineffectiveness) of fluid being prevented by the Turkish toweling tied around the distributing tip, and by gauze lightly packed into the outer wound opening (from Bickham, Operative Surgery, vol. i).

(3) An arranged supply of the solution that will guarantee a continuous flow of the fluid.

As the quantity of the fluid used is small in twenty-four hours, it is absorbed by the dressing and evaporates. The antiseptic is carried to the deepest recesses and diverticula of the wound.

Apparatus required for Carrel-Dakin irrigation:

(1) A series of conducting tubes.

(2) A series of distributing tubes.

(3) A reservoir for the fluid (see Figs. 1577, 1578).

The conducting tubes are of rubber. There are three varieties:

(1) Tubes perforated with small holes.

(2) Tubes with a single opening.

(3) Tubes perforated with small holes and covered with absorbent gauze.

The distributing tubes are of glass and are connected with the tubing of the reservoir of fluid and with the conducting tubes. There is the Y-shaped tube and there are tubes with two, three, or four stems.

The reservoir is a flask, the container fastened at a certain height above the wound with a tube and stop-cock attached.

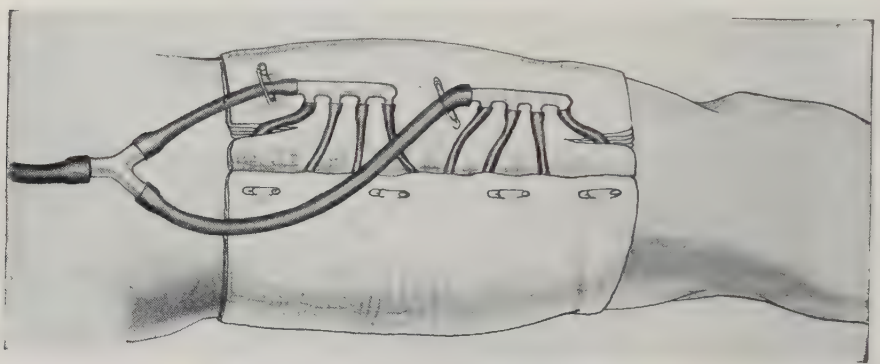


Fig. 1574.—Dressed wound, with the distributing tubes passing through the dressing. The secondary rubber conducting tubes (or the glass distributors) are anchored to the dressing by means of safety-pins (from Bickham, Operative Surgery, vol. i).

The tube from the reservoir connects through the distributor with the conducting tubes.

The arrangement of the tubes in the wound:

They must lie in actual contact with the tissues.

The fluid through gravity must flow over the whole extent of the wound surface.

These tubes are held in place by gauze compresses soaked in Dakin's solution. When the tubes are in place they are held by compresses. Additional compresses hold those compresses lying next to the wound. The adjacent skin surface is protected from being continuously bathed in the sometimes slightly irritating fluid by compresses covered with yellow sterilized vaselin.

The *dressing* is completed by large absorbent cotton compresses. The compresses are enclosed in sterile cheese-cloth or gauze layers. The secretions are absorbed by this dressing. The solution will thus be partly lost

by evaporation. No bandage is used. The dressings are held by swathe and safety-pins (see Fig. 1581).

The distributing tubes lie on the outside of the dressing and are held also by safety-pins (see Figs. 1575, 1576).

Fig. 1575.—A wound of the arm, Carrel-Dakin treatment. Note tubes to wound. Arm suspended by splint (Carrel).

In intermittent installation of the fluid the pinch-cock is released for a few seconds every two hours (see Fig. 1578).

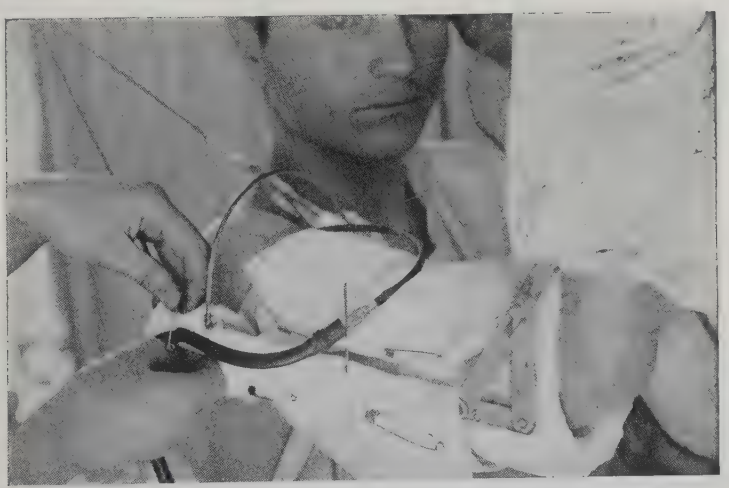


Fig. 1576.—A wound of arm, Carrel-Dakin treatment. Note tube to the wound supported by pins to prevent withdrawal of tube. Occlusion dressing. Arm supported in splint (Carrel).

The total quantity injected at each time will vary somewhat with the size of the wound—usually 20 to 100 c.c. are used. During the twenty-four hours some 250 to 1200 c.c. will be used.

The caliber of the rubber tubing is so calculated as to give an equal distribution of fluid through all the tubes.

There should be no overflow. There should be no pain. The sterilization of a wound should be followed, of course, by its closure. But a wound should never be closed until one knows what it contains. Suture of a wound containing bacteria may be followed by serious trouble. It is, therefore, only after the bacteriological study of a wound that one may safely approximate its edges.

This Carrel-Dakin-Dehelly method of treating septic wounds is most valuable. Its introduction marks an era in wound treatment. The method relies little on the patient's own recuperative powers during the first few days

Fig. 1577.—Carrel-Dakin treatment in case of compound fracture of the bones of the leg. Note glass container holding Dakin solution, the tubing leading to the tiny perforated rubber tubes in the wound. Note the ample absorbent dressing (after Carrel).

of the critical period. It is the most rapid method known of sterilization and rendering fit for secondary closure an infected wound. The dressings are painless—a marvelously valuable asset in the care of a sensitive, shocked, wounded, and discouraged man. The convalescence following this treatment is more rapid than convalescence following other methods of treatment.

The standard solution from which Dakin solution may be made up—manufactured by General Laboratories, Madison, Wis.—hyclorite (concentrated sodium hypochlorite[1]):

	Per cent.
Sodium hypochlorite	4.05
Sodium chlorid	3.20
Inert ingredients	92.75
Alkalinity (cal. hyd.)	$\frac{1}{6}$ of 1

[1] Accepted by the Council on Phar. and Chem. of A. M. A. (N. N. R.).

Fig. 1578.—Carrel-Dakin treatment. Nurse seen allowing a little Dakin solution to flow into the tube each two hours during the day to keep wound constantly bathed in the antiseptic (Carrel).

Fig. 1579.—Carrel-Dakin treatment of a compound fracture of leg. Note the rubber Carrel tube held by adhesive plaster in the wound (Carrel).

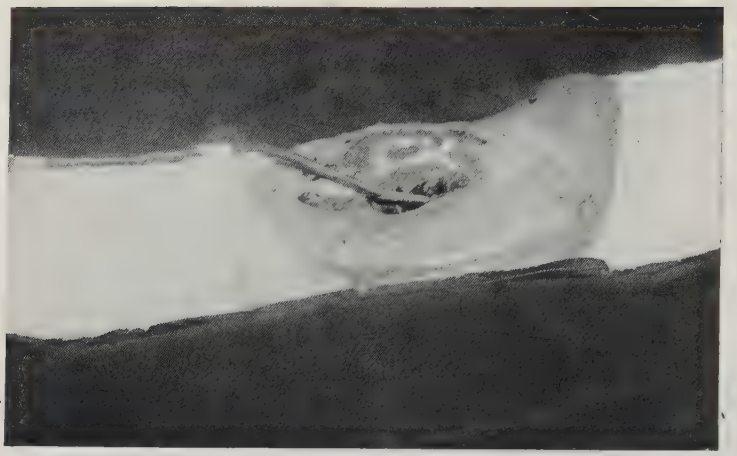


Fig. 1580.—Carrel-Dakin treatment. Compound fracture of leg. Note the Carrel tube lying in the wound (Carrel).

Fig. 1581.—Carrel-Dakin treatment. Note large absorbent and occlusion dressing; tube seen entering dressing on upper side (Carrel).

To Make Dakin's Solution

Dakin's Solution.—To make a hyclorite solution equal in hypochlorite strength to Dakin's solution (0.45 to 0.50 per cent. NaOCl) dilute 1 part of hyclorite with 7 parts of water. Allowance should be made for approximately 12 per cent. per annum decrease in hypochlorite content of hyclorite, that is, if one year old add 6 parts of water to 1 part of hyclorite. The date of preparation is stamped on every package of hyclorite.

A solution so made will have the correct hypochlorite strength (NaOCl 0.45 to 0.50 per cent.) and will be free from caustic alkalis. It will be found decidedly less irritating than Dakin's solution made by other methods. In fact, surgeons report that they find it practically unnecessary to protect skin edges with yellow petrolatum as in the case of solutions made by other methods.

Where especially rapid solvent action is desired in using Carrel technic on necrosed areas, dilute hyclorite as directed above, and then add 20 grams sodium bicarbonate to each gallon of Dakin's solution so made. Filter solution.

CHAPTER XXVIII

MASSAGE AND MOBILIZATION[1]

SOMEONE has said that the power to heal is the property of living tissue, but that the power to recover function, the use of muscles and joints, is the property of the patient's will.

Co-operation of Patient.—In other words, if the surgeon correctly diagnoses the injury and correctly treats it the co-operation of the patient is essential to a complete recovery—and nowhere will this co-operation be more helpful than in the mobilization of the part. The greater the co-operation, the more satisfactory will be the recovery.

Surgeon Should Be Informed.—It is extremely important that the surgeon caring for fractures should understand the principles and something of the practical working of massage and mobilization.

The principles underlying this special art find application in every fracture of a long bone without any exception.

Because of the universal applicability of the art of the mobilization of fractures it behooves surgeons to familiarize themselves with its methods. The treatment by massage and mobilization must be under the supervision and advice of the surgeon. The correct meaning of massage and active motion is not generally understood. What this form of treatment can accomplish is not commonly recognized. When in the course of a given case the treatment may be employed to the greatest advantage is unknown to most practitioners.

Hospitals Poorly Equipped.—*There is no systematic arrangement for the proper administration of early active motion or massage under personal direction in many hospital services. Hospital authorities do not yet comprehend the value of this treatment.*

Such active mobilization and massage must be prescribed and administered with a careful supervision which does not exist even in our best clinics. Each patient's problem and necessary treatment are still divorced from personal supervision. Many of the mediocre results following fracture are because of the lack of appropriately timed and supervised massage and mobilization. The daily massage and active movement treatment of a trained masseuse should be as much a part of the treatment of a fracture as the making of a fracture patient's bed or the serving of his meals.

Cases for Massage.—This form of treatment is applicable to:

(*a*) Fractures with no displacement of fragments and no tendency to displacement.

[1] With permission from Dr. James B. Mennell and his publishers, J. and A. Churchill, London, England, I have quoted freely from Massage, Its Principles and Practice.

(*b*) Fractures with displacement which can be reduced by relaxing muscle spasm.

(*c*) Fractures irreducible primarily by this treatment alone which can be benefited by massage preliminary to other treatment.

(*d*) Fractures after operative and non-operative treatment to hasten convalescence.

In appropriate places under the treatment of each fracture a word is said regarding the use of massage and mobilization. Regard is always had to the conceptions of massage and mobilization expressed in this chapter. To use massage correctly it must be considered entirely as a means to an end, the end being restoration of function.

Effects of Massage.—There are two effects to be expected from massage—reflex and mechanical.

The *reflex effect* of massage is as important as the mechanical effect.

The reflex effect is seen in the complete absence of pain following massage to a recent fracture; the muscular relaxation is apparent, the spasm disappears. The transient nature of the swelling at the seat and near the fracture is very evident whether the stroking is performed upward or downward.

The reflex arc in the child is highly sensitive and the fullest effect is thus secured rapidly. In the aged it is possible to cause fatigue with equal rapidity. Treatment, then, produces an irritative effect. In the young, therefore, and in the aged the duration of massage treatment should be curtailed.

Massage movements exert a *mechanical effect* by assisting the circulation of blood. By aiding the movement of the lymph. By stretching tissue, whether muscular, tendinous, or yellow fibrous elastic tissue.

In the treatment of a fracture massage rarely alone suffices to restore function.

As a sequel to and following massage in recent fractures there must be treatment by mobilization which consists of the employment of passive or relaxed movement and active movement.

Kinds of Movement.—*Relaxed movement* is used as a means of preparing the part for active movement, whether in the immediate or remote future.

Objects of Movement.—The objectives in view in administering relaxed or passive movement may be summarized as follows:

(1) Joints are kept supple.

(2) The formation of pathological bands and adhesions is prevented.

(3) Repair of all normal structures, even of bone, is hastened. Any attempt at movement which is inimical to their repair is attended by pain and reflex antagonism to the movement. Thus passive movement is rendered impossible.

(4) The elasticity of the muscles is maintained.

(5) The circulation of the venous blood and of the lymph is assisted materially, and hence the removal of waste products of extravasation and of edema is hastened.

(6) The restoration of any disorganization in the vasomotor system is probably assisted very materially—the main factor in effecting repair of injured structures.

(7) The joint sense is re-educated, or its loss is prevented, as the case may be, and thus the main link in the reflex of co-ordinated movement is restored or maintained.

(8) The way is paved for instituting active movement.

Just Lucas-Championniere was during his lifetime the most eminent champion of the use of massage in the treatment of recent injury. All his writing was not to extol the use of massage, but to advocate the reduction of immobilization to the minimum. With this in view, and with this only, did he originally advocate the use of massage. He valued massage little, save as a means to an end, that end being *mobilization*. In all else massage for him was an unknown power. It was only in recent years that he began fully to appreciate how much the effects of massage can assist recovery, even apart from the benefit conferred by the subsequent employment of mobilization. The latter, soon after injury, is impossible without the aid of massage. None the less the treatment of recent injuries by massage is not what he taught; it was always treatment by massage and mobilization that he advocated.

Dr. Mennell makes it very clear that it must be understood that in treating by massage a limb which has sustained a recent injury the massage is applied chiefly as a means of preparing the way for mobilization.

When to Employ Massage.—Until union is firm no form of massage is permissible over the injured segment of the limb, save only the gentle surface stroking. Even in performing this, the area of the fracture must be omitted from the stroke. It is well to begin the stroking over an area that is not sensitive, and gradually to extend the length of the stroke till the site of the fracture is approached. The stroke may then be increased to include the area beyond the fracture, only the actual site of injury being omitted.

Danger-signals.—When union is complete there are various danger-signals which must always be regarded. Any increase in tenderness at the site of the fracture is an indication for the cessation of mobilization and should be reported immediately. It indicates irritability of the callus due to strain at the site of union. An increase in swelling means that treatment the previous day has been excessive. The same deduction may be made if movement is more restricted or if there is an increase in stiffness. Massage is to be continued; mobilization reduced or omitted. Sudden onset of pain with swelling may be due to thrombosis; it should be reported at once, and no treatment should be administered till further orders are given. The patient's life may depend on this precaution. No one could be blamed for omitting treatment on the barest suspicion of this calamity; to overlook the symptoms is unpardonable. In addition to pain and swelling there may be a rise in temperature. The patient usually describes the pain as resembling cramp, and tenderness will be noted along a line in the long axis of the limb. If a superficial vein is implicated there will be redness, but probably there will be no redness if the vein lies deep.

Great care must always be taken adequately to support the ends of the broken bones. It must be remembered that in using mobilization there is always one direction in which movement can be applied that will tend to dis-

place the fragments more than movement in other directions; while it is usual to find that in one direction at least movement has no tendency to cause displacement. This movement is, of course, the first to be administered and prescribed respectively during the performance of relaxed or active movement. Similarly, any movement that tends to displacement is postponed until union is firm.

Passive Movement.—The confusion which exists as to what is meant by *passive movement* has, perhaps more than anything else, tended to postpone the more general adoption of the treatment of recent injury by mobilization. It must be realized from the outset that "passive movement" is impossible if there is any impediment to be overcome, or if the muscles assist or resist the movement. Also, it can only be performed when the joint is moved in the direction in which, during natural activity, there is the least possible strain on any structure surrounding it. Thus, extension of the elbow, if performed without due respect for the carrying angle, lays a strain on the external lateral ligament of the joint. The movement at once degenerates into a forced movement. To prescribe, as is so often done, treatment by "massage and passive movements" for a stiff joint would be ludicrous were it not for the great harm that such prescription produces. The masseur either relies on massage to effect that which it is impossible it should perform, or administers forced movement. In the latter event he may fail to discriminate between "passive" and "forced" movement; and, when true passive movement is required, he may do great damage.

From what has been said it will be evident that true *passive movement* can only find a very small place in physical treatment. So, too, does, or should, *massage*. But just as massage is frequently prescribed or given when voluntary effort on the part of the patient is the only thing that can cure him, so "passive" movement may also be given. Massage, used properly, in the right way at the right time, is one of the most valuable of physical remedies. Used in the wrong way at the wrong time it is never merely useless, but actively detrimental, mentally and physically. The same may be said of passive movement, though the harm done is never serious if the laws governing its administration are respected. Rather is it detrimental in so far as it can replace beneficial treatment in the form of active movement, and hence can retard recovery.

But though the place of passive movement in treatment may be small, it is one of the greatest possible importance in all cases of recent injury. It is, in short, the only prophylactic measure we possess by which we can reduce subsequent stiffness, rapid loss of power, and loss of the joint and muscle sense. One example alone will suffice. After fracture through the shaft of the humerus it may be impossible for the patient to move the elbow unaided for two to three weeks. Absolute fixation of the joint is the worst possible treatment it could receive, especially if there is any traumatic arthritis present as the result of the accident. The triceps and brachialis anticus also are bound, in greater or less degree, to be matted firmly to the site of fracture. So firm may their adherence become that movement of sufficient strength to

free them would tend severely to damage the union. Early mobilization, on the other hand, by pure "relaxed" movement may well have restored almost complete movement after a similar lapse of time.

In short, the aim of *passive movement* is to secure movement whenever active movement is, for any cause, impossible. This is its only justification; and, if there can be secured to the patient the benefits enumerated above during the whole or even part of the time that active movement must be withheld—at the one time of all others, be it noted, that these benefits are of the greatest value—then in passive movement we have a remedy that may be truly described as invaluable. *Forced movement* at the right time and place is of great service. Intelligent use of passive movement often reduces to a negligible extent the condition for which forced movement is required. There can be no possible excuse for substituting the one for the other in treatment, for between them lies another agency—potent for great good—unassisted *active movement.*

Voluntary Movement.—There is one maneuver which can often find a place in treatment, but which cannot be classed under the heading of "movement." It consists of teaching the patient to contract certain muscles, or groups of muscles, voluntarily without moving any joint as a result of the contraction. For example, the quadriceps can be exercised freely even though the knee-joint be firmly fixed; the deltoid can be made to contract without movement of the shoulder-joint. There are two requisites, a little tact and patience on the part of the masseur and perseverance on the part of the patient, if full benefit is to be reaped. Few things are more injurious to muscular strength than absolute rest; it is surprising how a very little exercise will maintain it. Even in the absence of joint movement the performance of the natural function of a muscle—alternate contraction and relaxation—will often suffice, if not to prevent wasting, at least to minimize it and to maintain its vitality. It will also help to maintain intact the muscle sense on which co-ordinated movement will subsequently rely.

Active movement may be divided into the following groups:

1. Free movement.
2. Assistive movement.
3. Resistive movement.

Treatment has aimed at restoring by massage any disturbance of *circulation,* and thereby has assisted the *repair of all injured structures.* Massage has rendered *movement* possible, and so has prevented the formation of adhesions, without interfering with *repair of the injured tissues.* The repair of tissue has been aided owing to the restoration of efficient circulation. In addition, the movement may in itself have helped to counteract the reflex set up by inimical stimuli.

A Warning Word.—Dr. Mennell very properly calls attention to an important matter in what follows:

Before leaving the subject of fractures it is necessary to utter a word of warning. Not every masseur is a fit person to be entrusted with the responsibility of treating a recent injury. If fracture is present, only those who

have received special teaching and training in the art should be asked to deal with it, and, even then, great care and discrimination are called for in selecting a masseur for a difficult case. Experience alone is inadequate in the absence of the necessary skill and temperament. To hand over a case of recent fracture to a masseur merely because he happens to be proficient in other branches of his work is to court disaster. The responsibility for failure belongs to the medical man who selected the masseur, so it is the duty of the physician to be sure that the masseur is qualified—by training, experience, skill, and temperament—for his highly specialized and very responsible duty. For the treatment of recent injury is an art apart. Under no circumstances can the medical man shift his responsibility for the position in which the fragments unite. If the result in this respect is faulty, he alone is to blame, as it was his duty to watch the position and correct errors while there was yet opportunity.

For a complete exposition of the subject of "massage" the surgeon is advised to consult Dr. Mennell's valuable book from which the above abstracts have been taken.

CHAPTER XXIX

BONE REPAIR

By Frederic W. Bancroft, M. D.,
New York[1]

The connective tissues—Embryology of bone: Hyaline cartilage, Progress of calcification to bone formation—Extra skeletal bone production—Theories of bone repair: Periosteal, Osteoblastic, Chemical—Repair of bone in fractures: Gross changes, Rabbit experiments, Microscopical changes—Physicochemical theories of bone repair in fractures—Summary of repair in fractures—Bone transplants: Experimental study, Factors favoring successful transplants, Fate of the bone-graft—Bone repair in chronic traumatic osteomyelitis—Reaction of bone to infection—Infected compound fractures—Formation of sequestra—Non-union and osteomyelitis.

THE CONNECTIVE TISSUES

The supporting, connecting, or connective tissue of the body (whose function it is to form the supporting framework for the organs and for the body) is characterized by a large quantity of intercellular or ground substance. This connective tissue is classified by the physical and chemical differences in the intercellular ground substance into three groups: connective tissue, cartilage, and bone. The connective tissues arise from the mesoderm of the embryo—the middle germinal layer.

These three varieties of tissue are closely related. When these tissues are closely associated or in juxtaposition there is no very distinct line to be seen between them. Each can replace the other.

The skeleton in certain animals may consist of connective tissue, or of cartilage, or of bone. Bone may develop from cartilage. Bone may develop from connective tissue. Cartilage may develop connective tissue in its substance.

Cartilage is distinguished from connective tissue by the firm consistency of its ground substance and its cells. It is transitional between connective tissue and bone tissue. The ground substance of hyaline cartilage is homogeneous and structureless and is filled with spaces containing cells—cartilage cells.

Bone possesses, as do the other supporting tissues, a large proportion of intercellular substance. The *diaphysis* of a long bone consists of compact bone substance, while the end or *epiphysis* is composed of a more open spongy bone. Beneath the cortical shell of compact bone are canal-like spaces, haversian canals, in which blood-vessels lie. Between and around these canals are smaller connecting spaces, lacunæ, containing bone cells. Around

[1] From the Laboratories of Surgery of Columbia University, New York, with appreciation for the advice and great assistance of Dr. William C. Clarke, director.

the haversian canals the bone lacunæ are arranged in concentric rows. From the fibrous periosteal covering connective tissue enters the bone on all sides.

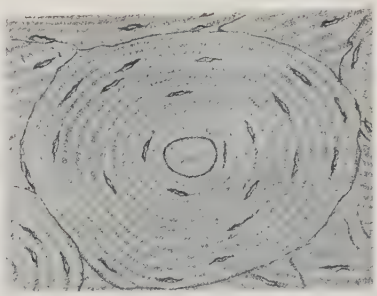


Fig. 1582.—Ground cross-section through the diaphysis of the human ulna viewed with polarized light (× 170). Note the haversian canal, lacunæ, bone cells and concentric arrangement. (From Szymonowicz and MacCallum, Histology.)

Bones considered as organs (see Figs. 1582–1586) are made up of bony tissue, periosteum, central bone-marrow, the latter consisting of blood-vessels and nerves supplying the different parts of the bone. The periosteum has an outer fibrous layer containing nerve plexuses and blood-vessels, and an inner

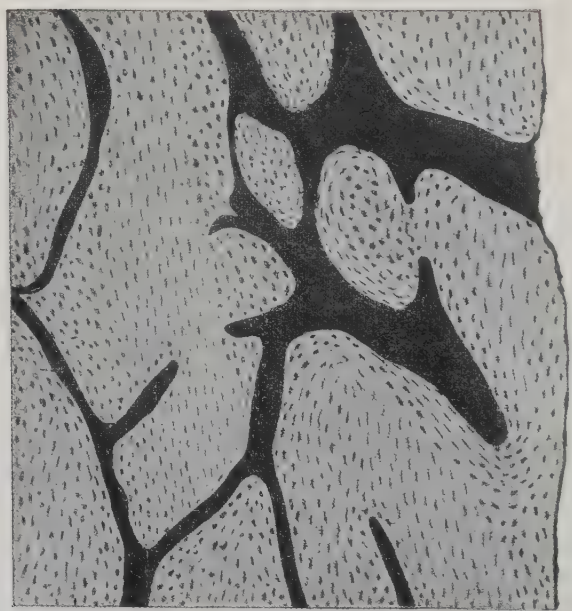


Fig. 1583.—From a ground longitudinal section through the diaphysis of the human ulna. All canals are filled with pigment, which is here black. Haversian canals are cut longitudinally (× 90). (From Szymonowicz and MacCallum, Histology.)

delicate, less vascular layer, rich in connective-tissue cells. In the inner layer of the periosteum lie cuboidal cells, osteoblasts, which may play an important part in the development and regeneration of bone. Throughout

the axial cavity of the long bone is a space filled with bone-marrow which enters the haversian canals. The bone periosteum and bone-marrow are

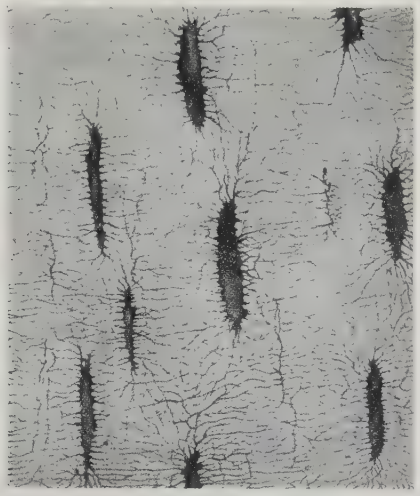


Fig. 1584.—From a section through the bone of a roebuck. The bone cavities are seen from the side (× 850). Note the delicate and multitudinous anastomosing canaliculi. (From Szymonowicz and MacCallum, Histology.)

supplied with blood-vessels. These enter the periosteum, supplying largely the outer lamellæ of the cortical bone. The blood-vessels of the marrow

Fig. 1585.—From a section through the bone of a roebuck. The bone cavities are seen from above and are filled with coloring-matter. In places small dots are visible, which represent the cross-sections of bone canaliculi (× 850). (From Szymonowicz and MacCallum, Histology.)

arise from the nutrient artery of the bone. There is an intimate capillary anastomosis between all the vessels.

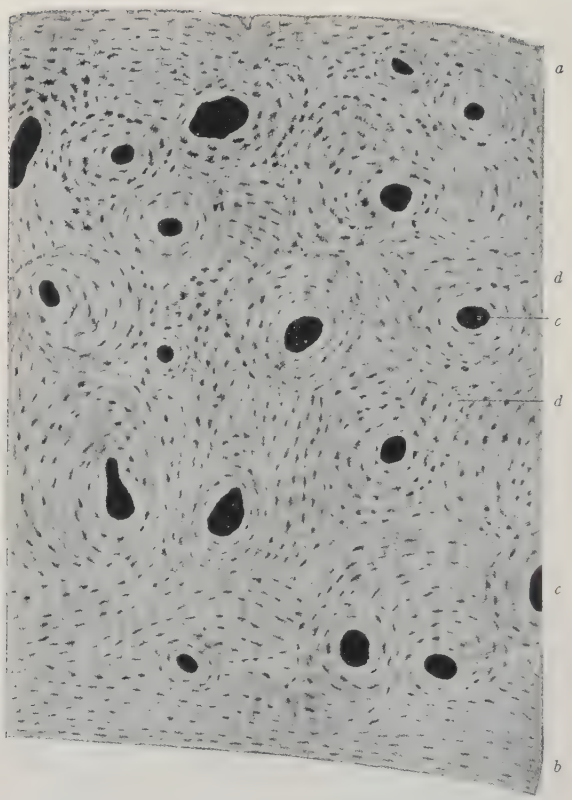


Fig. 1586.—From a ground cross-section of the diaphysis of the human metatarsus: *a*, Outer ground lamellæ; *b*, inner ground lamellæ; *c*, haversian lamellæ; *d*, interstitial lamellæ. All canals and bone cavities are filled with coloring-matter and appear black (× 90). (From Szymonowicz and MacCallum, Histology.)

The lymphatic vessels also form capillary networks in the periosteum. The nerves enter from the periosteum, passing through the bone and into the bone-marrow.

EMBRYOLOGY OF BONE

In the embryo bone is first represented by hyaline cartilage, which develops from the original connective tissue. The original cartilage of any bone corresponds very closely to the shape of the future bone. Surrounding the cartilage is a dense fibrous membrane, the perichondrium (see Figs. 1587–1590). In most cases ossification begins about the middle of a piece of cartilage corresponding to the shaft of the long bone (Fig. 1587). The cell spaces enlarge and in some cases the matrix between the enlarged spaces breaks down, so that several cells may lie in one space. The cell spaces radiate from a common center, but a little later they come to lie in rows parallel with the long axis of the mass of cartilage. During these early changes lime salts are deposited in the matrix of the cartilage in this region, and the portion involved is known as a calcification center (Fig. 1587).

So far the process is preparatory to actual bone formation. Then small blood-vessels from the perichondrium (periosteum) grow into the cartilage,

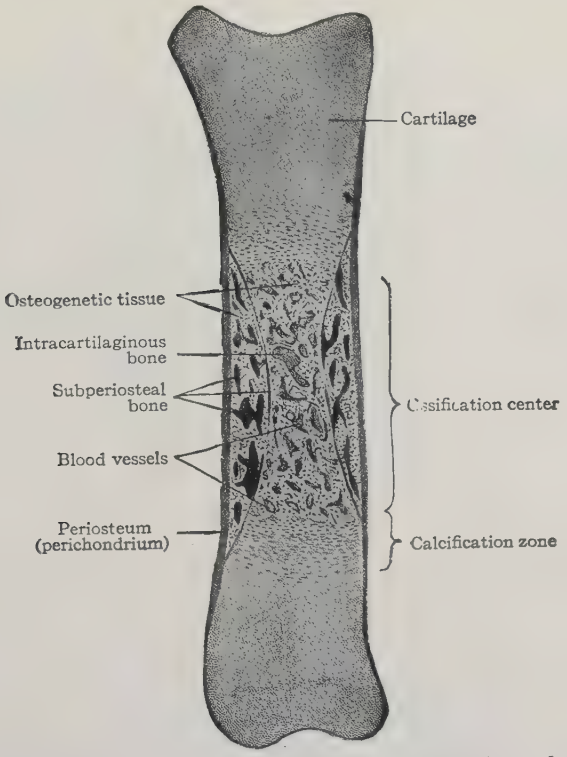


Fig. 1587.—Longitudinal section of one of the metatarsal bones of a sheep embryo. Intracartilaginous ossification (from Bailey and Miller, Text-book of Embryology, Wm. Wood & Co., Publishers).

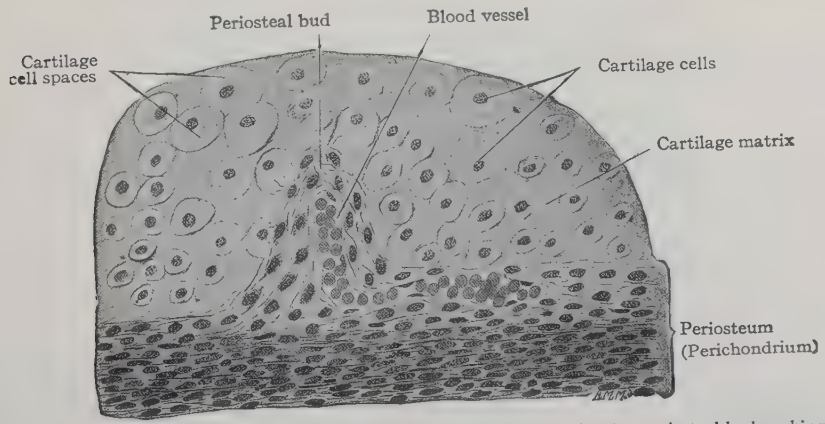


Fig. 1588.—From section of one of the tarsal bones of a pig embryo, showing periosteal bud pushing into the cartilage at the ossification center. Intracartilaginous ossification (from Bailey and Miller, Text-book of Embryology, Wm. Wood & Co., Publishers).

carrying with them some of the embryonic connective tissue (Figs. 1591–1595). These little ingrowths of connective tissue and small blood-vessels are known

as periosteal buds (Fig. 1594). The septa between the large cartilage cell spaces break down still further, forming still larger spaces into which the periosteal buds grow. Many of the connective-tissue cells are transformed

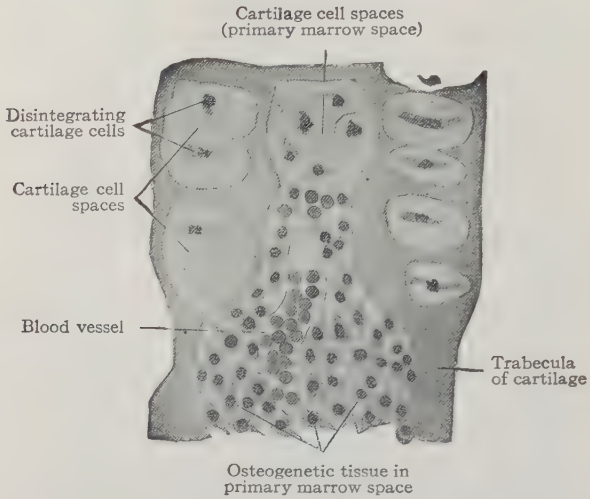


Fig. 1589.—From same section as Fig. 1587, showing osteogenetic tissue pushing into the cartilage and breaking it up into trabeculæ. Intracartilaginous ossification (from Bailey and Miller, Text-book of Embryology, Wm. Wood & Co., Publishers).

into osteoblasts, which with the fibers and blood-vessels constitute osteogenetic tissue (Figs. 1587–1590). The cartilage cells in this region disintegrate and disappear, and the cavity formed by the coalescence of the cell

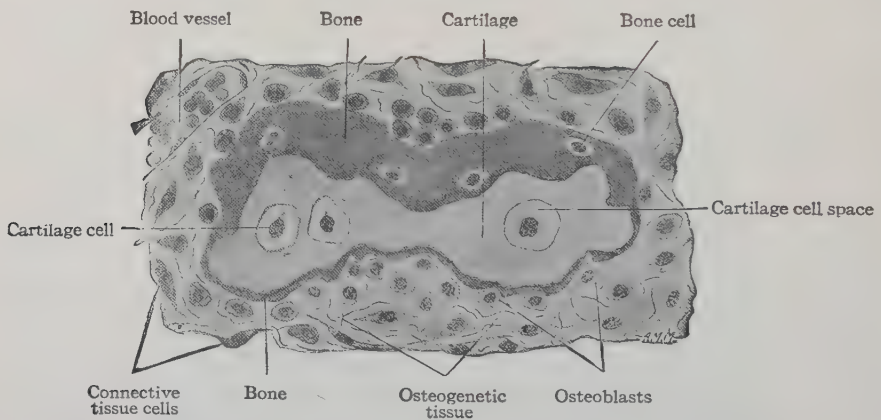


Fig. 1590.—From same section as Fig. 1587, showing bone deposited around one of the trabeculæ of cartilage. Intracartilaginous ossification (from Bailey and Miller, Text-book of Embryology, Wm. Wood & Co., Publishers).

spaces constitutes the *primary marrow cavity* (Figs. 1587–1590). From the primary marrow cavity osteogenetic tissue pushes in both directions toward the ends of the cartilage. The transverse septa between the enlarged car-

tilage cell spaces break down, leaving a few longitudinal septa, which form the walls of long anastomosing channels which are continuous with the

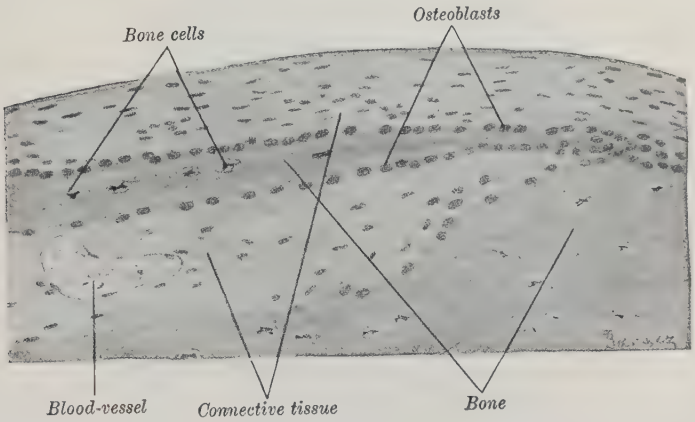


Fig. 1591.—From a transverse section of the parietal bone of a human embryo (×220). (From Szymonowicz and MacCallum, Histology.)

primary marrow cavity. The osteoblasts arrange themselves in rows along the septa of calcified cartilage and a thin layer, or lamella, of calcium salts is deposited between them and the cartilage (Fig. 1591). Successive lamellæ

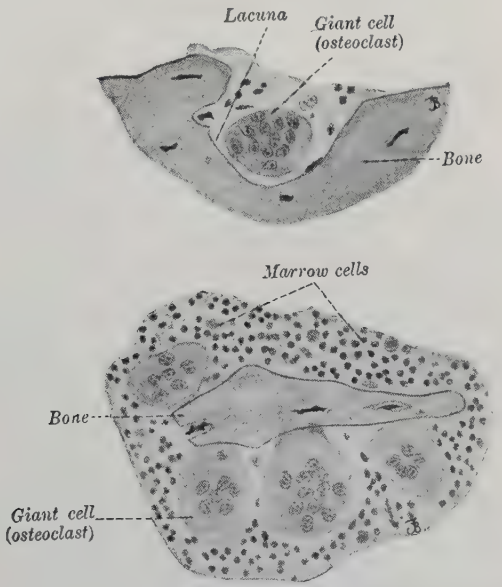


Fig. 1592.—From a longitudinal section of the femur of a rabbit's embryo (× 335). (From Szymonowicz and MacCallum, Histology.)

are deposited in the same manner and some of the osteoblasts become enclosed to form *bone cells* (Figs. 1587–1590). The cartilage in the center gradually disappears. This region, where bone formation is going on, is known as an

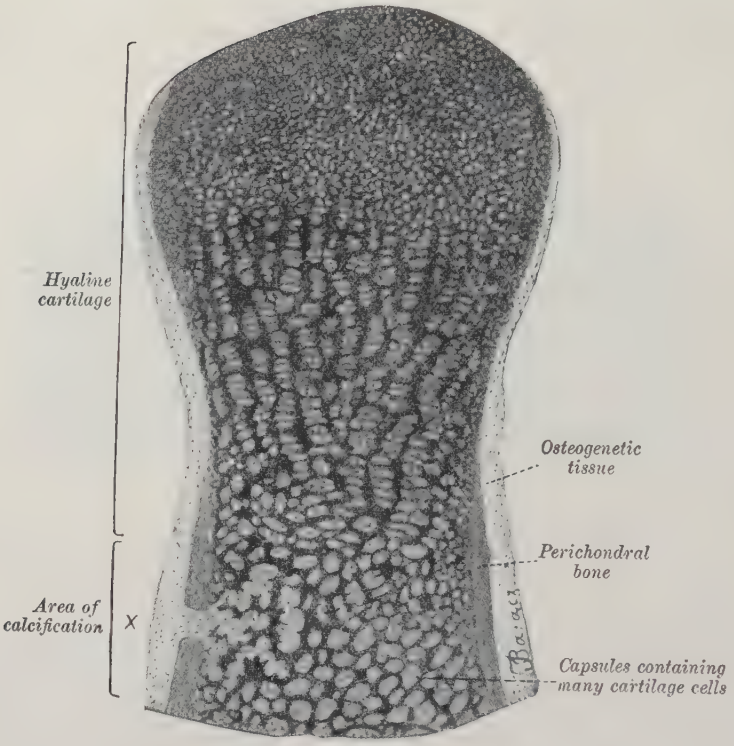


Fig. 1593.—From a longitudinal section of a finger of a three and a half months' human embryo. Two-thirds of the second phalanx is represented. At × a periosteal bud is to be seen (× 85). (From Szymonowicz and MacCallum, Histology.)

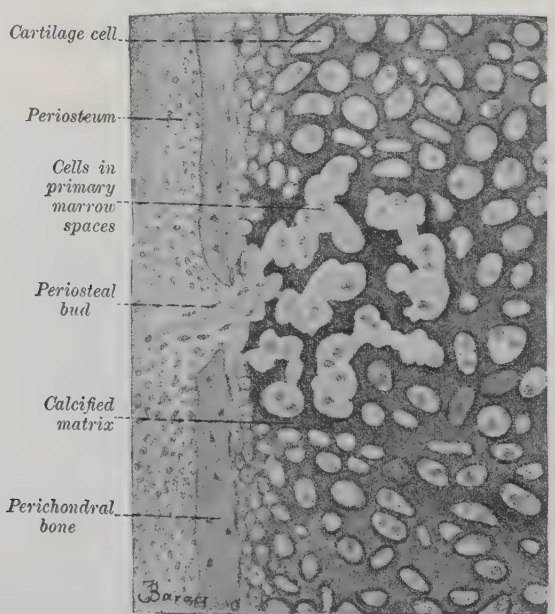


Fig. 1594.—The place marked × in the preceding figure with stronger magnification (× 185) (From Szymonowicz and MacCallum, Histology.)

ossification center (see Fig. 1595), and the irregular anastomosing trabeculæ of bone with the enclosed marrow spaces constitute *primary spongy bone.*

From this time on ossification gradually progresses toward each end of the cartilage, and at the same time a special modification of the cartilage precedes it. Nearest the ossification center the cartilage cell spaces become enlarged and arranged in rows and contain cartilage cells in various stages of disintegration. Some of the septa break down and others become calcified (see Fig. 1595). Passing away from the center of ossification, there is less

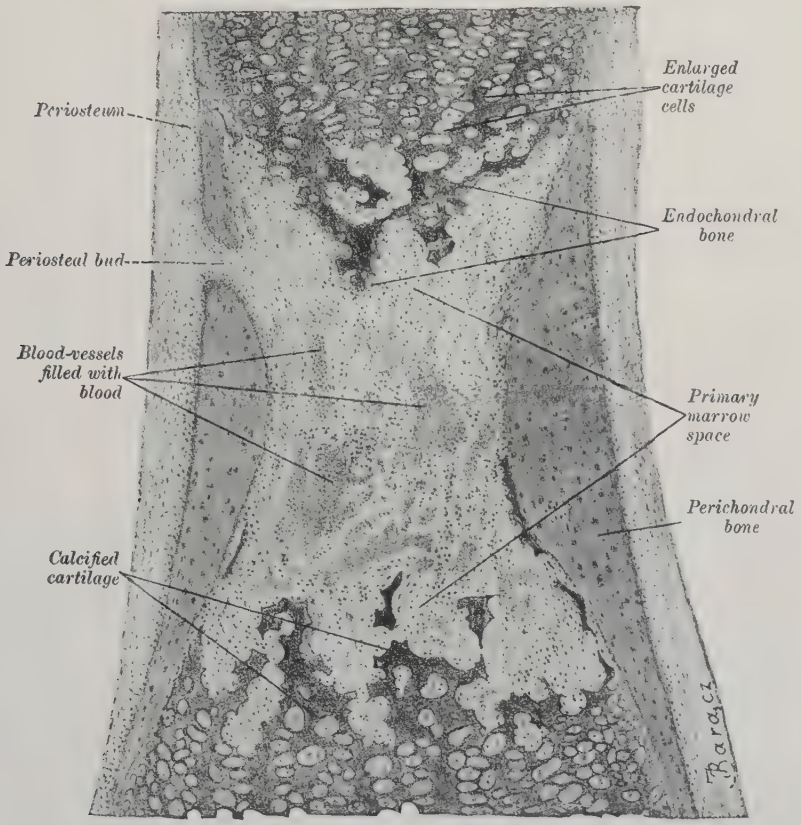


Fig. 1595.—From a longitudinal section of a finger of a four months' human embryo. Only the diaphysis of the second phalanx is represented (× 85). (From Szymonowicz and MacCallum, Histology.)

enlargement of the cell spaces and they have a tendency to be arranged in rows transverse to the long axis of the cartilage; there is also a lesser degree of calcification. The region of modified cartilage at each end of the ossification center passes over gradually into ordinary hyaline cartilage and is known as the calcification zone. It always precedes the formation of bone as the latter process moves toward the end of the cartilage (see Fig. 1593).

Along with the type of ossification just described subperiosteal ossification also occurs (see Figs. 1594, 1595). Beneath the periosteum (perichondrium) is a layer of connective tissue, certain cells of which are osteoblasts. They

deposit layers of calcium salts on the surface of the cartilage in the same manner as around the trabeculæ inside the cartilage. All the bones are formed from cartilage with the exception of the bones of the roof of the skull, the lateral part of the skull, most of the face bones, and a small part of the base of the skull.

INTRODUCTION TO THE STUDY OF BONE REPAIR

We know little of the exact detail of what happens in the repair of any connective-tissue structure of the body. The physicochemical factors involved, especially those of nerve regulation and of stress and strain, are practically unknown.

Through microscopical appearances we are familiar with certain biological facts, but why they begin, continue in orderly sequence, and cease happening is still unknown. Consider, for example, a small lacerated wound. We know that hemorrhage takes place first; that connective-tissue cells grow into the fibrin of the blood-clot, and that eventually organization occurs, with resulting scar tissue formation. How connective tissue originates and why it ceases growing is a mystery. If we could follow the course of one cell through its entire history in this process we might hope to obtain some information concerning this problem.

When we study the repair of bone the problems involved are difficult. Here we have a connective tissue with its matrix impregnated with calcium salts, making the study of the chemical factors very intricate.

Living Bone and Dead Bone Contrasted.—We have been accustomed to compare living bone with the bone that we see in prepared skeletons, which leads to a wrong conception, for living bone is constantly changing its shape. For instance, incidental to physical changes that occur in certain orthopedic conditions, the lines of stress and strain are altered, and as a result the architecture of the cancellous bone changes. The processes involved in this change are not known. A further example is the change in the shape of the lower jaw that occurs if a tongue is removed. Experiments by McEwen show that rings placed about long bones in young animals are eventually covered by new bone as growth occurs. Many surgeons have noted that bones in limbs which are kept for a period of time in splints show atrophy and a loss of calcium salts, both by *x*-ray and by gross examination. We may conclude that bone is a constantly changing structure and is much more pliable than we have previously conceived it to be. Bone is a flexible tissue.

Bone is a connective-tissue structure with its intercellular stroma impregnated with calcium salts. Herein lies the essential difference from other tissues in repair, whether from infection or injury. If bone is killed, we have to deal with a calcified matrix, which may persist as a foreign body. If bone is infected, portions of it may become a sequestrum. For the completion of a reparative process following a fracture it is necessary that there be a calcification of the connective-tissue stroma.

EXPERIMENTAL EXTRASKELETAL BONE PRODUCTION

We are apt to consider merely skeletal bone in our theories of bone formation, but bone occurs pathologically in many structures of the body. It occurs in lymph-nodes, arteries, tumors, etc., and in almost every connective-tissue structure. Extraskeletal bone can be produced easily in animals by various experimental methods.

Neuhof, working in the Laboratory of Surgery at Columbia University, used fascia lata to fill defects in the urinary bladder in dogs. Sections of these transplants showed lamellar bone with haversian canals and marrow in the transplants immediately beneath the regenerated epithelium. Extraskeletal bone resembles skeletal bone in its gross and microscopical appearance and its chemical analysis.

THEORIES OF BONE REPAIR

Any theory of bone formation, therefore, must be broad enough to explain embryonic bone formation, bone repair after injury, and pathological and experimental extraskeletal bone. There are three main theories advanced to explain the repair of bone:

I. The periosteal theory.
II. The osteoblastic theory:
    A. The osteoblast, a specific cell.
    B. The osteoblast derived from metaplasia of connective-tissue cells.
III. Deposition of calcium salts in the intercellular stroma of connective tissue.

I. The **periosteal theory** assumes that the periosteum and endosteum are the main structures utilized for osteogenesis.

Until Macewen's work, this was the generally accepted theory among clinicians. Experimenters had attempted to show that in transplants bone could be formed from transplanted periosteum, and that bone transplanted without periosteum entirely disappeared. Much of this work has been subsequently disproved.

It is obvious that one could argue that periosteum could not be stripped off from adherent bone without bone cells being transplanted with it. On the other hand, transplanted bone contains haversian canals with projections through them of the endosteum, so that one could not state that bone was transplanted without periosteum or endosteum. No explanation under this theory can account for the pathological or experimental bone.

II. **Osteoblastic Theory.**—A. The osteoblast is a specific cell. Many writers, including Macewen, believe that the bone is formed by osteoblasts. They assume that when a fracture occurs, bone cells are liberated from lacunæ and these reproduce and form the new bone.

B. That the osteoblast arises by metaplasia from the fibroblast or connective-tissue cell and that it acts as an osteogenetic cell.

The first subgroup of this division explains embryonic and skeletal bone formation, but it is difficult to understand how bone could be reproduced

experimentally, as in Neuhof's fascia lata experiments, or how bone could be produced pathologically by wandering osteoblasts.

Practically all types of bone formation could be explained by the theory that osteoblasts arise by metaplasia from connective tissue.

III. **Deposition of Calcium Salts in the Intercellular Stroma of Connective Tissue.**—This theory assumes three things: (1) That there is no definite bone-producing cell, and (2) that calcium salts are deposited in the intercellular stroma of connective tissue, and (3) that the fibroblast becomes a bone cell through functional adaptation. It has no active part in bone formation, but is merely a passive agent.

Calcification and Ossification.—Wells assumes that calcium phosphate and calcium carbonate, the principal salts of bone and calcific deposits, are held in solution by the colloids of the blood plasma, and that their solubility is enhanced by the carbon dioxid of the blood. When this colloid material comes into contact with a hyaline material, such as the osteoid tissue of developing bone, or the degenerated matrix of calcifying tissue, there is assumed to be an absorption of the calcium salts into the matrix.

If the carbon dioxid be now diminished there follows, as a consequence, the precipitation of the salts, and these processes of absorption and precipitation may be conceived of as proceeding rhythmically until the hyaline matrix is saturated with calcium salts.

Since the proportion of the constituent salts of the blood is determined by their relative solubility in the plasma medium, it follows that they will be precipitated in bone and in calcific deposits in the same relative proportion. This supposition has been verified by experiments, for analysis of bone and of calcareous deposits have revealed the fact that not only are the salts the same, but their relative proportions are also, in general, the same.

These facts have led Wells and others to look upon calcification and ossification as expressions of the same physicochemical process, the only essential difference being that in ossification the processes involved are under cellular control, whereas in calcification they are not.

We believe that this last theory explains bone formation in the embryo, in repair, and in types of extraskeletal bone. This theory makes more simple our treatment of bone pathology.

In our treatment of bone injury or infection we must attempt to produce the right chemical and biological state, then the process of bone formation will inevitably follow.

In our future studies we must determine if possible the circumstances of bone production, that is, what factors promote its formation.

REPAIR OF BONE IN FRACTURES

In a study of the repair of fractures we will consider a simple fracture of a long bone and study the gross and microscopical changes and what we know of the physicochemical events.

I. **Description of Gross Changes in a Fracture.**—Fractures of long bones are caused either by direct or by indirect violence. A fracture by direct

violence has such a force exerted that muscles, nerves, and vessels must likewise be traumatized. A fracture due to indirect violence must similarly injure the soft tissues by means of the fractured ends of the bone. We, therefore, consider a fracture not only a broken bone, but an association of injuries to muscles, vessels, and nerves, and in the region of a joint possibly there will be joint injuries. The immediate posttraumatic reaction must be intense. The broken ends are somewhat displaced. The periosteum is torn and stripped more or less extensively from the bone by the fracture and by the associated hemorrhage. Hemorrhage occurs throughout muscle bundles and tends to follow fascial planes (Fig. 1597). Hemorrhage takes place from the marrow under the periosteum. The subcutaneous ecchymosis so frequently seen is often due to blood seeping through various tissue planes and reaching the skin. The swelling of the fractured limb is due in part to the inflammatory exudate. The blebs and bullæ of the skin are occasioned by the elevation of the superficial layers of the skin as the fluid exudate extends toward the surface of the part affected. Much fat may be set free from the broken bone and be taken up into the circulation.

Between the fractured ends there is extensive bleeding. If the periosteum is not torn, this bleeding may be limited by it, but in fractures wherein displacement occurs, the periosteum is usually torn and extensive hemorrhage extends away from the bone ends. Edema may occur as a result of local chemical irritation due to hemorrhage and laceration of lymphatics. Clinically we often see tremendous swelling of a limb in a short time after the injury.

If a fracture is explored four or five days after injury, there is found a beginning organization of the semi-elastic blood-clot. At about ten days, one finds a thick, tenacious-like material, the early callus, which joins the bone ends and invades adjacent muscle bundles (Figs. 1598, 1601, 1602). This callus has a peculiar consistency.

If a rabbit's bone is broken and not treated, so that the ends overlap, we have found on cutting down on the fracture after seven days and excising the surrounding muscles, that the bone ends can be freely moved in a lateral direction, but that it is almost impossible to draw these ends apart so that the overriding is obliterated. We have here then only the factor of the tenacious callus because the muscles have been excised and muscle spasm has been eliminated. This experiment demonstrates why at times it is impossible to reduce the existing deformity of a fracture even with the patient under an anesthetic. A steady traction maintained over a considerable period of time, however, will overcome the deformity.

If, in the above experiment, this callus is cut into and scraped with a knife, gritty particles will be felt. These gritty particles are the signs of a beginning ossification of the connective tissue. In about a month one finds, on exposing the fracture, that the signs of hemorrhage into the muscles have largely disappeared. The callus has been partly absorbed, and around the fracture ends, often invading the muscles, one finds an ovoid, firm mass which can be cut with difficulty, and if the reparative process is progressing favor-

ably, only slight motion can be detected between the broken bone ends. As repair progresses the callus assumes more the natural shape of the bones and union occurs.

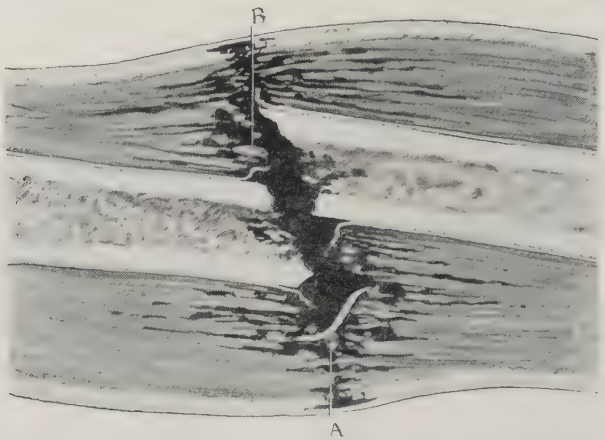


Fig. 1596.—Diagrammatic sketch of a fracture showing the injury produced: Note the blood extending through muscle planes, laceration of muscle tissue. A indicates a damaged nerve-fiber. B indicates a torn blood-vessel.

II. **Microscopical Appearances in Fractures.**—Immediately following a fracture a series of changes occurs in the tissues about the injured part. There

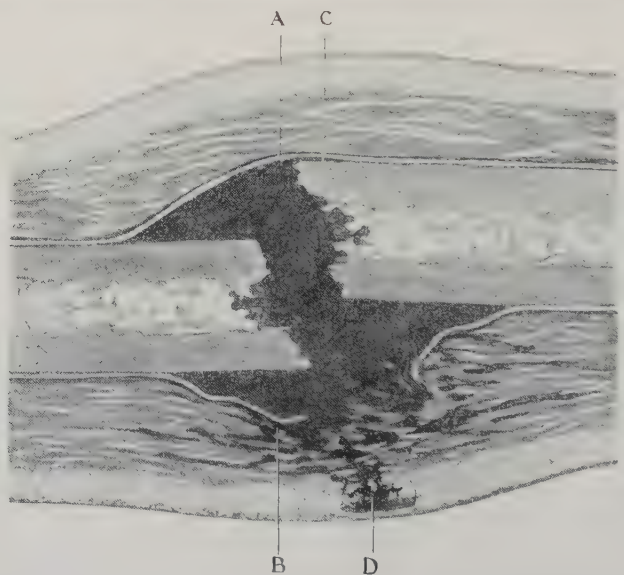


Fig. 1597.—Repair following fracture: A, Unlacerated periosteum with definite limitation of the blood from hemorrhage; B, laceration of the periosteum allowing the extension of the hemorrhage into the surrounding soft parts; C, lacerated end of the cortical bone; D, ecchymosis into soft parts, even to subcutaneous tissues.

is an escape of the blood-vessel contents, that is, serum, leukocytes, red blood-cells, with the formation of fibrin from the serum. The tissues immediately

about the injured bone are infiltrated with this material. The hemorrhage lies also under the stripped-up periosteum. After about five days the fibrin formed has begun to contract and early granulation tissue is seen growing in from the periphery of the clot. Even at this stage one can see areas of

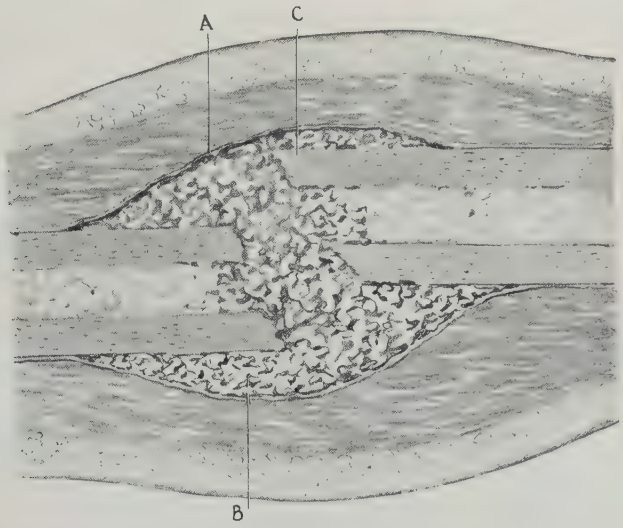


Fig. 1598.—Repair following fracture. Preliminary callus output; view of fracture illustrated in Fig. 1596 about two weeks following injury: A, Periosteum; B, osteoid tissue (see Fig. 1599), photomicrograph.

denser staining in certain areas (Figs. 1601, 1602) of the granulation tissue, which is, apparently, the beginning deposition of calcium salts within the intercellular stroma. At about ten days connective tissue is well organized and there are seen numerous new blood-vessels (Figs. 1603 and 1605). This

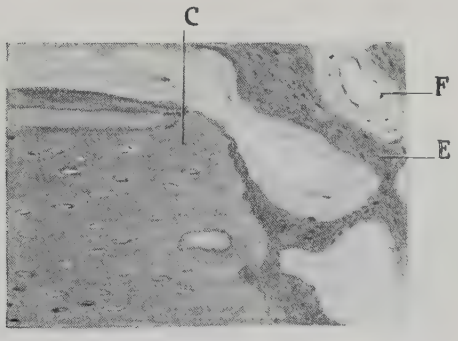


Fig. 1599.—High-power appearances of the fractured end of the cortex from Fig. 1598: C, End of cortex showing absence of bone nuclei, atrophy, and demineralization; E, osteoid tissue forming in the avascular zones of the new granulation tissue; F, a section of a blood-vessel.

formation of new cells and new blood-vessels to replace destroyed or damaged tissue is spoken of as the process of repair. Ultimately the exudate disappears and the newly formed tissue of cells and blood-vessels is changed into or becomes connective tissue. In the perivascular areas one can see very defi-

nite osteoid tissue (see Figs. 1603 and 1605). At this stage there is quite a definite arrangement of blood-vessels, areolar tissue, and osteoid tissue. No specific cell can be identified. There is gradual transition in the appearance of the cells from connective tissue to osteoid tissue to bone (Figs. 1600, 1601).

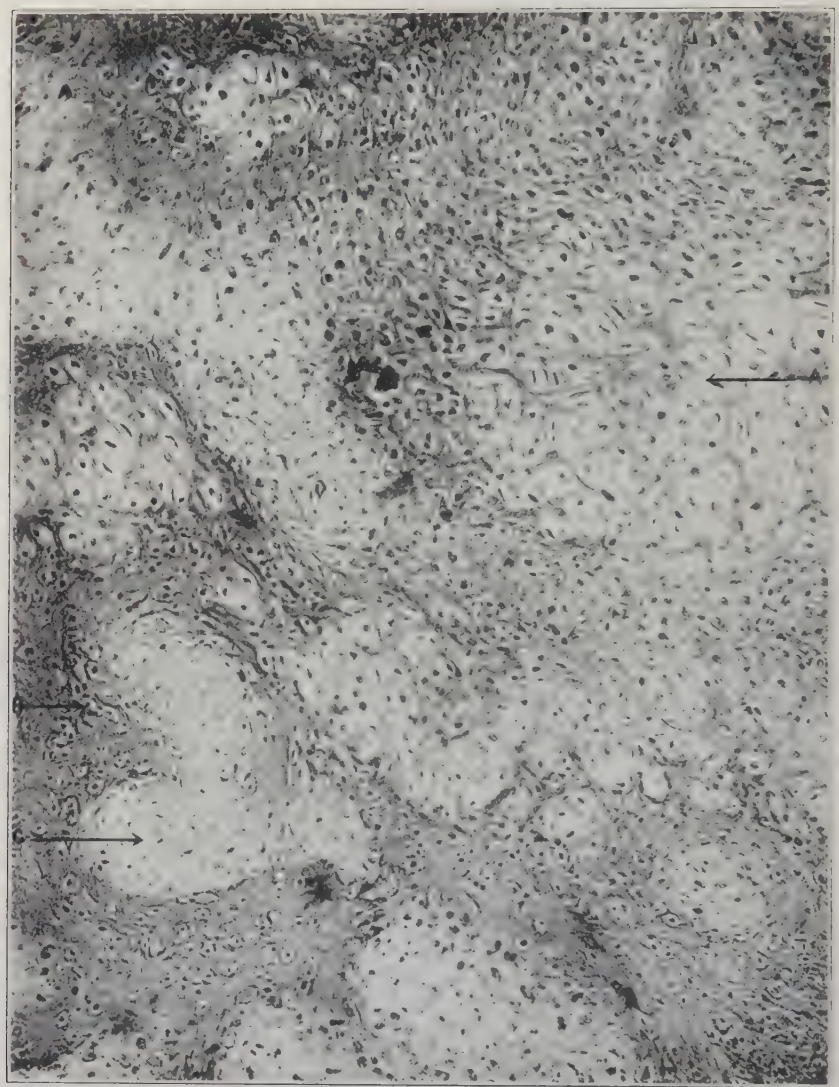


Fig. 1600.—Early bone formation following fracture: *A*, Cartilage; *B*, new bone; *C*, connective tissue. Gradual transitions are observed from connective tissue to cartilage, from connective tissue to bone, and from cartilage to bone. No distinctive cells are seen.

Where the periosteum has been torn the same arrangement of osteoid tissue can be seen extending out into the muscles.

Occasionally one sees areas of hyaline cartilage or fibrocartilage (Fig. 1600). The significance of the cartilage is not wholly apparent. The theory

has been advanced that where there is false motion, cartilage forms in the early process of repair. Here again one finds a transition of connective-tissue cells, cartilage cells, and bone cells. At the periphery of the mass it is diffi-

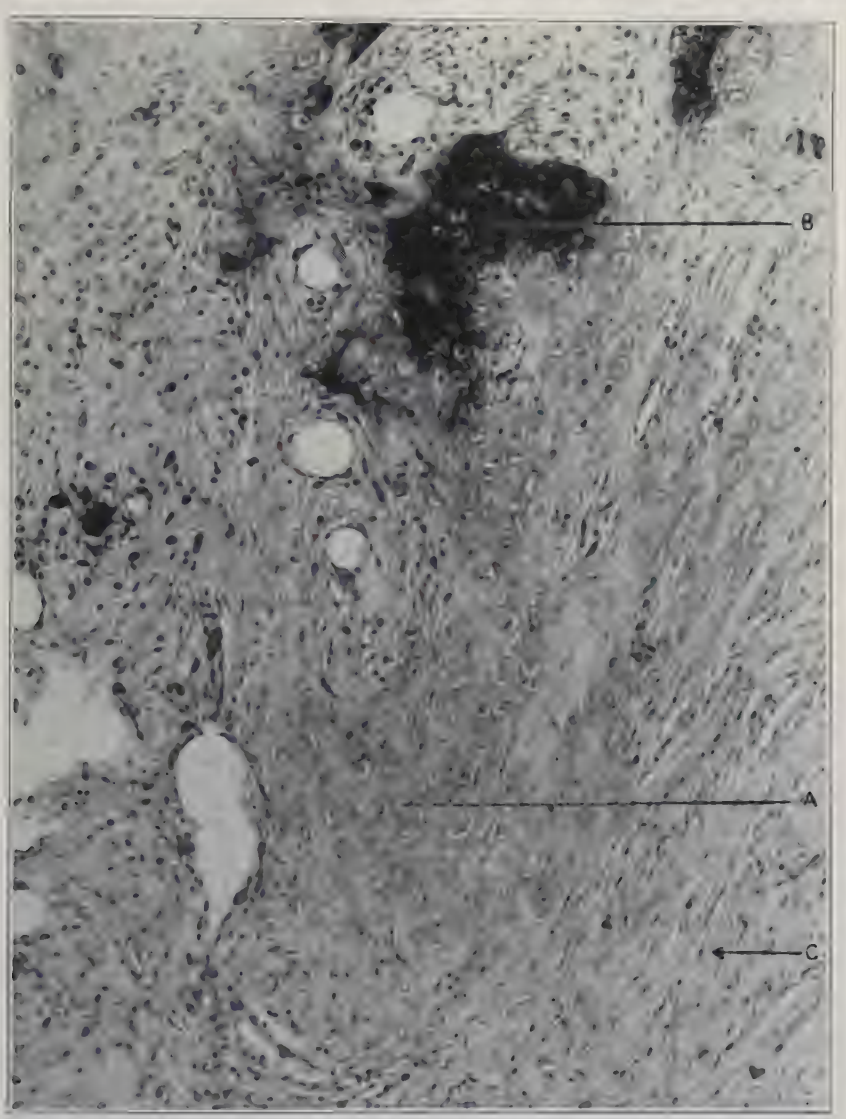


Fig. 1601.—Scrapings removed from fractured humerus of a human being twelve days after injury: *A*, Fibro-cartilage; *B*, early bone; *C*, connective tissue.

cult to tell where a connective-tissue cell ends and cartilage cells begin, or where cartilage cells end and bone cells begin (Figs. 1600, 1601).

Marked changes are noted in the ends of the fractured bones (Figs. 1599 and 1605). The nuclei are absent in many of the bone lacunæ, and there are numerous large spaces in the ends of the bone which are apparently due to

absorption of both matrix and cells. This *atrophy* of the bone ends is quite a noticeable factor, and one that has not been sufficiently emphasized.

Sections taken at later periods show the lobular arrangement described in early callus, but the osteoid tissue is increased at the expense of the areolar

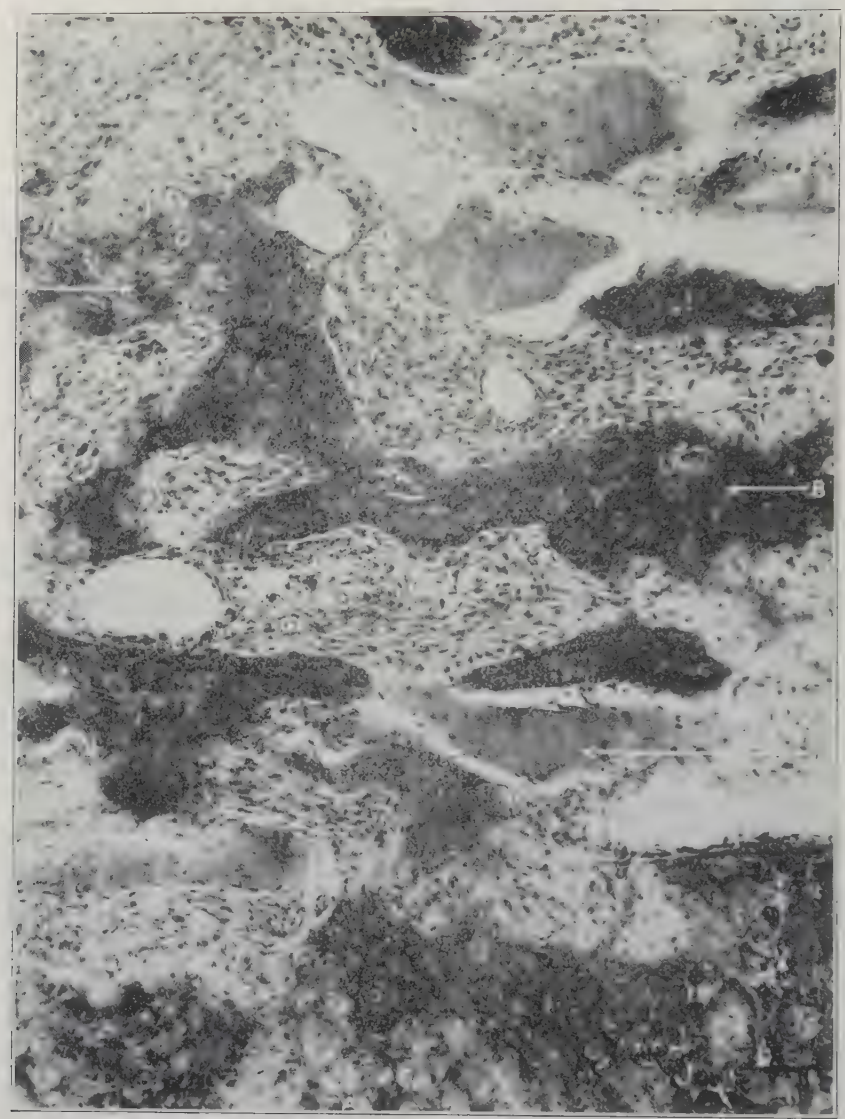


Fig. 1602.—Ossification occurring in the midst of muscle-fibers twelve days following a fracture of the humerus in an adult: *A*, Ossification occurring in cartilage; *B*, early bone; *C*, connective tissue; *D*, degenerating muscle-fibers.

tissue. New bone is formed in trabeculæ and not in solid masses. This continues until a definite haversian canal system appears. Calcium is apparently re-absorbed from the excessive callus seen in the early sections

and scar tissue results. Sections taken several months after injury show the re-establishment of the medullary canal and definite cortical bone, which is, however, of less density and contains more spaces for connective tissue than the normal cortical bone.

Fig. 1603.—Callous formation seventeen days following fracture, showing deposition of calcium salts in the avascular zones in early connective tissue.

The arrangement of the haversian canals at the zone of the fracture is at right angles to the cortex rather than parallel to it as in the normal (Fig. 1606). This is presumably due to the fact that, in general, the new blood-vessels growing into the original granulation tissue were derived from the

surrounding soft tissues outside the bone and grew in this direction. Undoubtedly a certain number of blood-vessels grow outward from the bone-marrow. The re-alignment of the vessels of the cortex probably does not take place until after a year.

Fig. 1604.—Comminuted fracture of radius and ulna in rabbit ten days following injury: *A*, Interosseous membrane; *B*, medullary canal of radius with cortex on either side; *C*, new bone forming in connective tissue following hemorrhage around the fractured ends and across the medullary canal; *D*, detached bone fragments surrounded by new bone formation; *E*, medullary canal of ulna.

A fibrous tissue membrane surrounds the bone and replaces the periosteum which has been stripped from the bone. This differs from the normal periosteum in that it has not the areolar tissue in the immediate proximity of the cortex.

It is a well-known clinical fact that marked comminution of the bone is associated with a greater output of callus than in the case of a linear fracture (Fig. 1604).

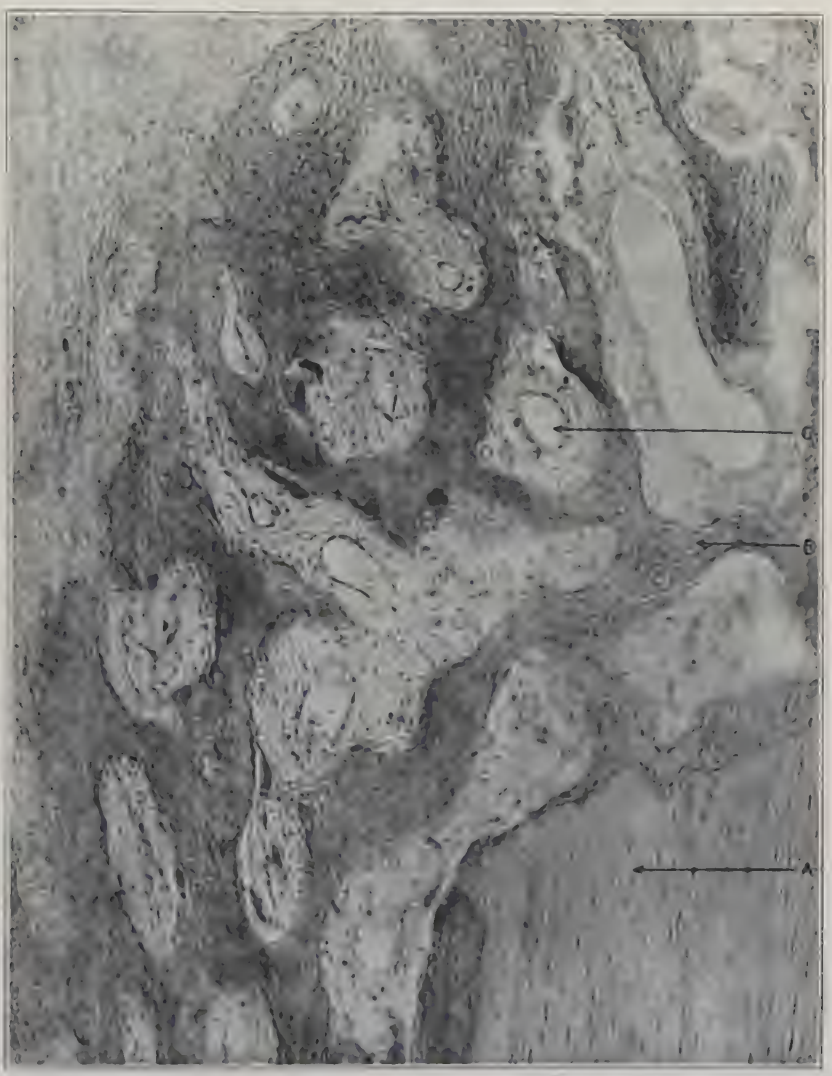


Fig. 1605.—High-power magnification of radius and ulna shown in Fig. 1604: *A*, End of fractured shaft showing atrophy at end with absence of bone nuclei; *B*, new bone formation in the connective tissue; *C*, areolar connective tissue with newly formed blood-vessels.

III. **Physicochemical Theories of Bone Repair in Fractures.**—Howland and Kramer found that the serum in tissue fluids of normal infants contains calcium phosphate in a nearly saturated solution. A slight reduction of the acidity of the tissue fluid at a point in which the cartilage is in close contact with the circulation from the bone-marrow reduces the solubility of these

salts, resulting in their precipitation. As a result of the foregoing work and also from the study of calcium and phosphate concentration in the serum of rachitic infants, Tisdall and Harris tried to find if the same fundamental principles applied with the deposition of calcium salts in the treatment of fractures. They found that in children from four months to nine years there was 5.4 mg. of phosphorus to 100 c.c. of blood-serum, and that in adults from twenty to forty-four years there were 3.8 mg. of phosphorus to 100 c.c. of serum. Studying adults with fractures, they found that the calcium content remains about the same, but that the phosphate is increased from 3.8 to 5.3 mg. This returns to normal at about eight weeks after fracture. In 2 cases of non-union both the calcium and phosphorus were only slightly increased.

When a bone is broken a certain amount of tissue is damaged and more or less blood is extravasated, coagulated, and autolyzed. It has been shown,

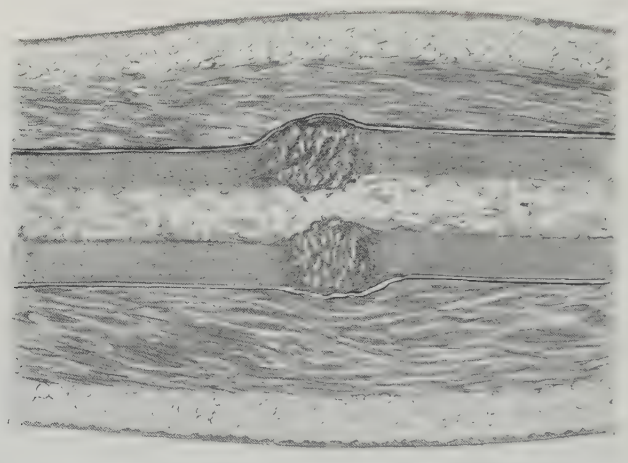


Fig. 1606.—Fracture at about nine months following an injury, showing re-establishment of the medullary canal. The cortex, however, shows enlarged haversian canals often running at right angles to the long diameter of the shaft.

experimentally, that these substances resulting from trauma can take calcium from the broken ends of the bone, so that the soft tissues about a fracture are richer in calcium than normal tissues. It has also been shown that the phosphate content of the blood during the process of repair is greater than at other times.

These calcium, phosphate, and carbonate ions are free in the acid medium, that is, they are in solution. With the growth of granulation tissue and the formation of the hyaline matrix of the newly formed trabeculæ, these ions enter the trabeculæ and become concentrated there. It must then be supposed that the hydrogen-ion concentration within the trabeculæ is lowered, that is, it becomes more alkaline. When this reaches a certain point below that of blood plasma, ionization occurs and triple calcium phosphate and calcium carbonate are precipitated as insoluble salts.

It is an interesting observation that, as far as we know, the processes of calcification and ossification are physicochemically similar. The only difference is, that in the case of ossification we are dealing with precipitation of these salts about living cells and with a free circulation in the immediate vicinity, while with calcification, there are no living cells and there is no active circulation in the calcified zone.

Watt[1] very clearly discusses the evidence for the various theories of bone formation, the summary of which I herewith present.

Evidence is in favor of the calcium being carried in the blood as the soluble double salt, calcium carbonophosphate. This correctly explains the carrying of the salts to the bone, to which it supplies both carbonate and phosphate in exactly the proper proportion. But from this stage onward evidence is in favor of the view that this salt is taken from the blood and deposited in the bone by the action of osteoblasts.

There is a calcium balance similar in its workings to the well-known carbohydrate balance. The carbohydrate balance is between the sugar content of the blood, the liver cell, and the liver's reserve store of glycogen.

Sugar is removed from the blood by the hepatic cells and deposited as glycogen when the content in the blood is high. The reaction is reversed when the blood is poor in sugar. Similarly, with a normal calcium content in the blood, the osteoblasts can obtain and deposit bone salts, but with blood poor in calcium the reaction will be reversed, salts being removed from the bone to raise the calcium content of the blood to normal.

The calcium in the bones is thus a great alkali reserve in a state of flux.

Barille has shown that calcium salts are transported to the bone in the form of a complex double salt, calcium carbonophosphate. Evidence favors the view that the salts in bone are deposited by activity of the osteoblasts, as a secretory phenomenon.

There is a calcium balance between bone matrix osteoblasts and blood similar to the carbohydrate balance between glycogen, liver cell, and blood.

SUMMARY OF REPAIR IN FRACTURES

From the gross, microscopical, and physicochemical findings we may summarize the process of repair of fracture as follows:

1. The immediate result of fracture is a hemorrhage which may extend into muscles, fascia, and skin (Fig. 1596).

2. The organization of the blood-clot occurs by the ingrowth of connective tissue (Figs. 1601, 1602).

3. Calcium salts, calcium phosphate, and calcium carbonate are deposited on the connective-tissue stroma in the perivascular areas (Figs. 1603, 1605). These salts are carried in the blood system, partly by colloids and partly by carbon dioxid. The change of the hydrogen-ion concentration in the vicinity of a fracture with a decrease in the acidity apparently causes their precipitation. Calcium phosphate, yellow phosphorus, and

[1] James C. Watt, Toronto, Archives of Surgery, May, 1925.

cod-liver oil, when fed by mouth, have apparently aided the production of callus in some cases of delayed union.

4. The supply of calcium salts apparently comes from two sources: From the circulating blood and from the fractured ends of the bone by a process of demineralization and atrophy.

BONE TRANSPLANTS

As the greatest amount of experimental work on bone has been undertaken in the study of bone transplants, a review of the various steps in our knowledge has been delayed for this section. The opinions of investigators concerning bone repair and the fate of bone transplants, of the function of the periosteum and endosteum, are so divergent that one must attempt to formulate some simple theory without real adequate proof.

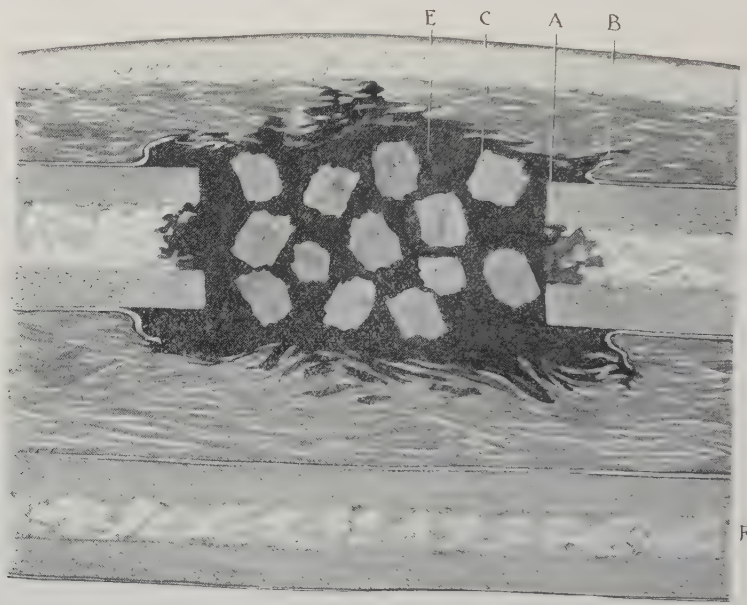


Fig. 1607.—Semidiagrammatic drawing of the bone fragment operation: *A*, Cut end of shaft of radius; *B*, periosteum stripped back from radial shaft; *C*, bone fragment lying free in blood-clot *E*; *F*, ulna.

Experimental Study of Bone Transplants.—In order to study the fate of bone transplants by the simplest experiment I removed about 2 cm. of the shaft of the radius of dogs. The excised piece was then denuded of its periosteum, split longitudinally, and the endosteum removed as far as feasible. The piece removed was then cut into small fragments 1 to 2 mm. in diameter, and these fragments were inserted into the bone defect (Fig. 1607). The muscles and skin were then united and the leg put up in plaster.

Sections, taken at about ten days postoperative, showed a well-defined callus uniting the fragment (Figs. 1608–1612). On microscopical examination,

this callus appeared as osteoid tissue described in the discussion on frac-

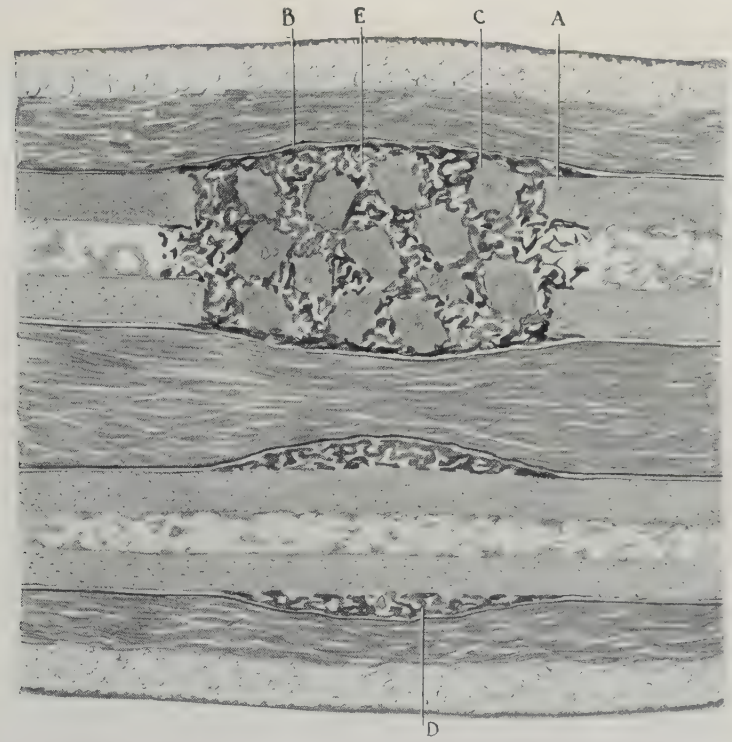


Fig. 1608.—Drawing of bone transplant operation two weeks following the injury: *A*, Cut end of radius showing some bone atrophy and demineralization; *B*, newly formed periosteum which resembles any fibrous tissue capsule; *C*, bone fragments showing atrophy and absence of nuclei; *R*, osteoid tissue occurring in granulation tissue; *D*, compensatory subperiosteal bone formation in the uninjured ulna.

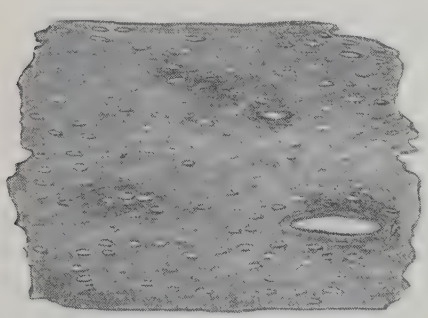


Fig. 1609.—High-power appearance of bone fragments about two weeks following operation. No nuclei are seen in the bone lacunæ. There is marked atrophy of the bone.

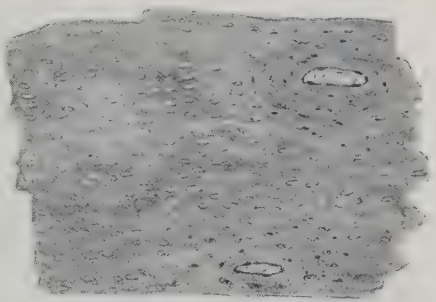


Fig. 1610.—Appearance of bone fragments about four weeks following the operation. Revascularization of the haversian canals is apparent, showing newly formed blood-vessels with red blood-cells in them. Two or three layers of active bone nuclei are seen in the lacunæ surrounding these blood-vessels.

tures (Fig. 1604). The fragments at this period showed no nuclei present in the bone lacunæ (Figs. 1608, 1609). The staining reaction was less dense

than the normal bone, and there were areas of rarefaction (Fig. 1612). At about three weeks the callus had become much denser, and on microscopical examination showed well-defined osteoid tissue, with blood-vessels and some areolar tissue (Figs. 1608, 1612). The fragments at this time showed blood-vessels containing living red blood-cells in the larger canals (Figs. 1610, 1613). About these canals two to three layers of well-stained nuclei appeared in the bone lacunæ. Later studies showed a gradual disappearance of the bone transplants and a well-defined new bone about them (Figs. 1611, 1614). At the end of a year the shaft had been fairly definitely re-formed so that it was difficult to see where the transplants had been placed.

Microscopical sections showed here and there areas of lacunæ with absence of nuclei, and in general the cortex consisted of well-formed bone with its

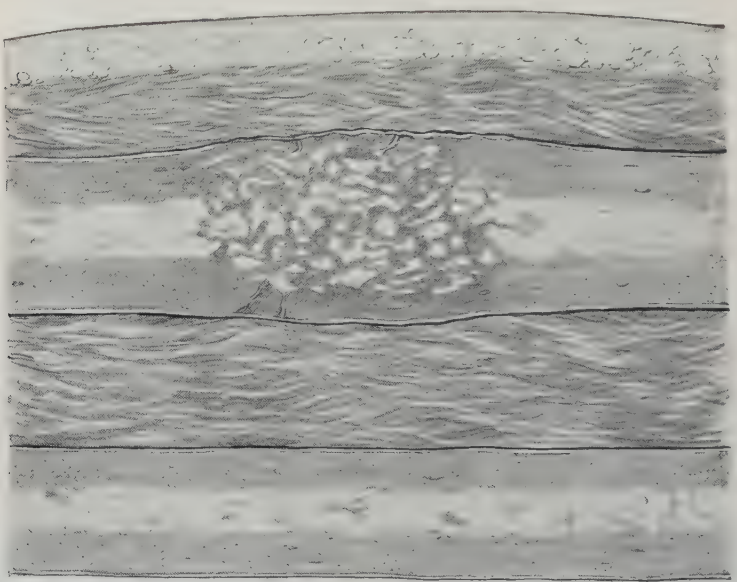


Fig. 1611.—Diagrammatic sketch of bone transplant operation about one year subsequently. Beginning re-establishment of haversian canals and of the cortex; bone fragments have disappeared; haversian canals frequently run at right angles to the cortex.

medullary canal fairly well defined. The direction of the haversian canals in the cortex was perpendicular to the long axis of the shaft, differing from normal bone, in which the course of the haversian canals is parallel to shaft (Figs. 1611, 1614).

We see, then, from these experiments that transplants do not of themselves live, but act as an osteoconductive skeleton and are prone to stimulate deposition of calcium salts in the connective tissue in their immediate vicinity, thus producing osteoid tissue.

Factors Favoring Successful Bone Transplants.—From my experiments and from clinical deductions we believe that the following factors are necessary for a successful bone transplant:

1. It must be strong enough to maintain the shape of the limb, unless this can be accomplished by external support.

Fig. 1612.—Transplantation of bone fragments to fill defect in radius one hundred forty-one days following operation: *A*, Ulna; *B*, radius; *C*, bone fragment; nuclei do not stain; areas of rarefaction near periphery; *D*, new bone formation about periphery of fragments; *E*, cartilage forming false joint.

2. The transplant must be so placed that it can have its blood supply quickly established.

3. In general the greater the surface exposed, the more osteoid tissue produced. This is shown in ordinary comminuted fractures where the amount of callus is in excess of that in a linear fracture.

Fig. 1613.—Bone transplants four weeks following operation: *A*, Haversian canal with re-establishment of blood-supply and surrounded by one or two layers of active bone nuclei; *B*, absence of nuclei in bone distant from haversian canal.

McWilliams, in a thorough analysis of the methods of bone-grafting, came to the conclusion that the periosteum upon a graft had very little influence upon the ultimate success. He analyzed the end-results of about 1390 cases where grafts had been used. Of these, 1170 with 82.9 per cent. successes, had

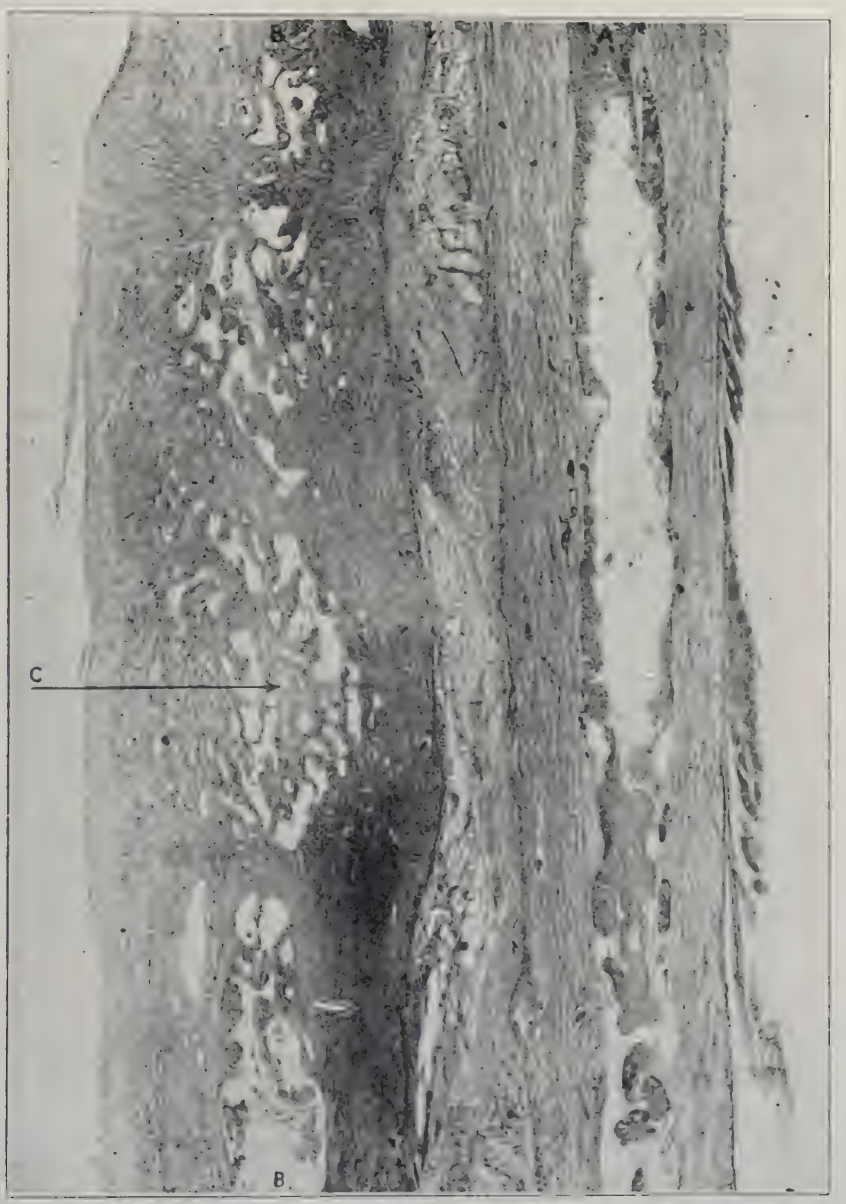


Fig. 1614.—Transplantation of bone fragments to fill defect in radius three hundred forty-seven days following operation: *A*, Ulna; *B*, radius; *C*, beginning formation of medullary canal. The entire zone shown in the illustration is the area in which the transplants were placed. It is no longer possible to detect the fragments, but a new cortex and medullary canal are being established by the gradual absorption of the fragments and the formation of new bone.

periosteum, while 196, with 82.6 per cent. successes, were without periosteum. In analyzing the types of transplants he found that the successes were relatively as follows:

	Per cent.
Bone pegs	95.8
Osteoperiosteal (Olier and DeLangeniere)	87.3
End to end (without inlay)	82.5
Inlay	80.9
Intramedullary	76.6

If we summarize this analysis we may understand why the results are as shown above.

Bone pegs are surrounded completely by bone and very quickly have their blood-supply re-established.

The osteoperiosteal grafts of DeLangeniere are thin strips of bone and periosteum which are laid down between the ends of the bone (p. 990). If they are sufficient to maintain the shape of the limb, theoretically they are the most practical, for the blood-supply is very quickly established. They offer a large surface of raw bone to stimulate osteogenesis.

The inlay graft is, as a rule, rather thick and does not offer so much surface of raw bone for stimulation of osteogenesis. The late fractures that occur in these cases are probably due to the slow re-establishment of the blood-supply and the resulting atrophy of the transplant.

We are inclined not to use the intramedullary graft. We know that the main blood-supply of the shaft of the long bone is from the nutrient artery. In applying an intramedullary graft we destroy the blood-supply of both fractured ends of the shaft, and undoubtedly a longer time is required for repair on account of this to re-establish the blood-supply of the graft.

Clinically it would appear advisable to transplant periosteum with the transplant because it seems logical to assume that adhesion of connective tissue to connective tissue, as between periosteum and the surrounding tissues of the host, will grow more rapidly than adhesion of connective tissue to bare bone.

We may also assume that the quicker the adhesion occurs, the sooner the blood-supply will be re-established.

It is probable that some types of fibrous tissue, bone, and cartilage can live without a definite blood-supply. Loose cartilages in the knee-joint without pedicles have shown microscopically living connective-tissue cartilage and bone cells. This may explain why certain types of transplants continue to have staining nuclei of the bone cells at their periphery. They may be nourished by fluids of the body independently of a visible vascular supply.

Fate of the Bone-graft.—The clinician and the laboratory worker have held contradictory opinions in regard to the persistence of bone transplants. Surgeons have stated that transplants live because they persist in the *x*-ray and because, if at a subsequent operation the transplant has been cut, it has bled.

The laboratory worker has stated that transplants do not live because on microscopical examination there is an absence of the bone nuclei.

If, however, we study the results of the bone fragment transplantation we see an answer to this dispute. The matrix undoubtedly shows in the *x*-ray, and as the blood-supply is re-established in the graft from two to three weeks following operation, the surgeon's deductions are obvious. The microscopical study shows that if we assume that the presence of cells with normally staining nuclei are an evidence of the life of tissue, the grafts *per se* do not live.

BONE REPAIR IN CHRONIC TRAUMATIC OSTEOMYELITIS

Infections in bone because of the anatomical structure are much more complicated than infections in connective tissue. When we consider that bone consists of a rigid calcified matrix containing its blood-vessels and nerves in narrow rigid channels, we will realize why this is true. The shaft of long bones receives its blood-supply almost entirely through the nutrient artery. The periosteum supplies the circumferential lamellæ. If the nutrient artery becomes thrombosed the death of a large portion of the shaft may result. In connective tissue when edema and hyperemia occurs the surrounding tissues dilate, thus compensating for the increased vascularity. In bone the edema and congestion of the vessels within rigid walls is more apt to result in thrombosis and subsequent death of tissue. If infection persists in connective tissue, an abscess forms, with the breaking down and liquidation of the cellular and extracellular structures. In bone, with the persistence of infection, the cellular structures may be destroyed and the matrix may persist as an irritating foreign body. Proceeding further in this, we understand why infections of bone in children and in adults also differ. In children the calcification of the stroma is less dense than in adults. In infancy infections in bone more closely resemble infections in connective tissue, as the calcified stroma is of less density and pus readily escapes from the medullary canal before severe circulatory injuries occur.

THE REACTION OF BONE TO INFECTION

Three main reactions to infection occur in bone: First, necrosis, death of tissue *en masse*, causing destruction of the cellular elements with persistence of the calcified matrix. This is usually the result of sudden overwhelming infection, which occludes the blood-vessels of the part. The sequestrum that occurs in acute hematogenous osteomyelitis is the best example. Second, osteoporosis or caries—a destruction of both stroma and cellular elements. Caries is the result, usually, of a chronic infection which does not occlude the circulation before a compensatory blood-supply can be established. It is usually due then to a chronic infection persisting over a considerable period of time. Brody's abscess in bone is a good example. Third, osteosclerosis, a reparative process which resembles scar tissue formation of ordinary connective tissue. In osteosclerosis the calcified content of the matrix is often increased so that we have eburnation of bone.

INFECTED COMPOUND FRACTURES

When a compound fracture occurs the skin, fascia, vessels, and nerves are usually traumatized. The bone is frequently comminuted and often fragments are separated from periosteum and their blood-supply. With the onset of infection the pieces of bone become irritating foreign bodies, and if not expelled are surrounded eventually by either scar tissue or scar tissue of bone, the involucrum.

In compound fractures infection may produce an acute osteomyelitis of a virulent type with concurrent septicemia. If the process proceeds without surgical relief, a thrombosis of the nutrient artery may occur, with a resultant sequestration of a large portion of the shaft.

FORMATION OF SEQUESTRA

We may subdivide the sequestra that occur in chronic traumatic osteomyelitis following compound fractures as follows:

1. Primary sequestra, wherein a fragment is separated from the cortex and its blood-supply at the time of the original trauma.

2. Secondary sequestra, wherein a spike or fragment of bone is separated from the shaft except at one end. With the onset of the infection its blood-supply is interfered with and separation often occurs at its origin from the cortex.

3. Tertiary sequestra, wherein secondary infection spreads over a large distance of shaft, causing an acute osteomyelitis and the death of the bone at some distance from the original point of injury.

Sequestra in adults persist as irritating foreign bodies, frequently without any reduction in size, over a period of years. It has been shown by Taylor and others that bacteria may be found in the interstices of the sequestra years after the original infection.

The persistence of this irritating foreign body is the main difference between infections of soft tissues and bone. The reparative process in bone tends to defeat its purpose. The foreign body—infected bone—lies in a cavity, which eventually becomes surrounded by new bone with an intervening area of débris and infected granulation tissue.

THE DEAD SPACE IN BONE

While a small sinus frequently extends through the involucrum to the surface, it is impossible for the foreign body to escape. This is the problem that the surgeon has to face; even with the removal of the foreign body the problem is not half-solved.

In connective tissue, with the release of pus, the dead space is obliterated by, first, the ingrowth of granulation tissue; second, the pressure of the surrounding parts; and third, the contraction of the scar tissue. In some large infected wounds of connective tissue there is failure of healing because as the granulation tissue grows inward there is scar tissue formation at the periphery with a resultant contraction. If the process of healing is sufficiently

delayed, either through the chronicity of the infection or the poor resistance of the host, the contracting scar tissue interferes with the blood-vessels extending into the granulation tissue, and we have areas of necrosis formed. One sees this in old war wounds where there is sluggish granulation tissue and epithelization proceeds for a certain distance over the granulation tissue and then breaks down. In these cases wide excision of the scar tissue with a secondary suture is often the only method of cure.

Fig. 1615.—Osteomyelitis in a dog caused by the injection of Staphylococcus aureus in the medullary canal: *Sq.*, Cortical sequestrum. Marked new bone production tending to wall off medullary canal and compensatory subperiosteal bone proliferation on the opposite side. Figures 1615–1618 are from the same case.

In bone, when we have removed the sequestrum, we have the problem of the dead space. Only one of the three factors which tend to obliterate the dead space in connective tissue operates in obliterating the dead space in bone, namely, the ingrowth of granulation tissue. This is the reason that it is so difficult to obliterate the dead space in bone. The granulation tissue grows a certain distance, then the resultant scar tissue interferes with the circulation and there is breaking down and suppuration. A similar situation is familiar to all of us in chronic empyema, where the rigid chest wall often makes the obliteration of the dead space a difficult surgical problem.

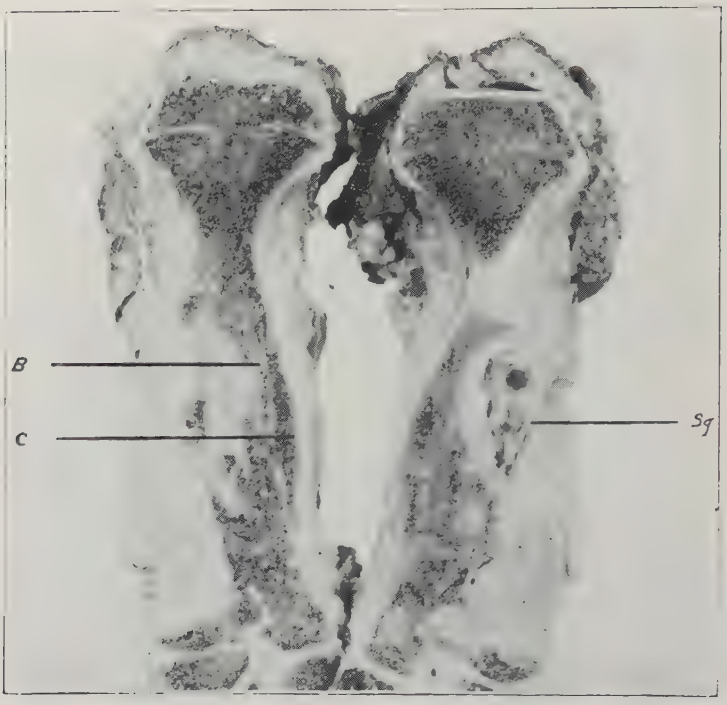


Fig. 1616.—Cross-section of bone: *Sq.*, Sequestrum; *B*, rarefied cortex; *C*, subperiosteal bone proliferation.

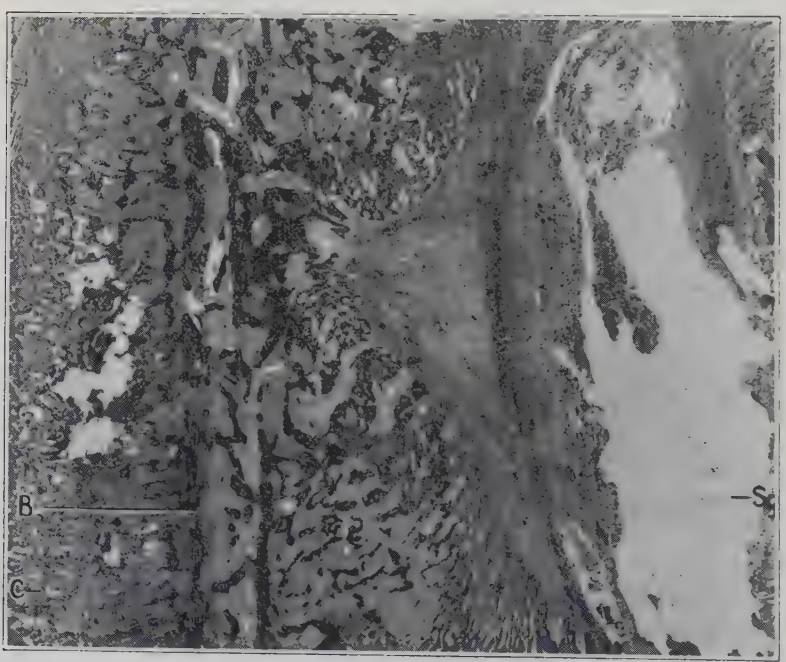


Fig. 1617.—Low-power photomicrograph: *Sq.*, Cavity in which the sequestrum shows granulation tissue with new bone production in the medullary canal; *B*, rarefied cortex surrounded by areas of leukocytes and infected granulation tissue.

The accompanying illustrations (Figs. 1615–1618), the result of an experimental production of osteomyelitis in dogs, show fairly graphically some of the pathological conditions that occur in chronic traumatic osteomyelitis following compound fracture in human beings. This animal was originally inoculated with a strain of Staphylococcus aureus isolated from a case of hematogenous osteomyelitis, then transmitted through a dog and isolated from its blood-stream.

The humerus of another dog was exposed; the periosteum was stripped back in order to destroy as far as possible the nutrient artery, and a burr

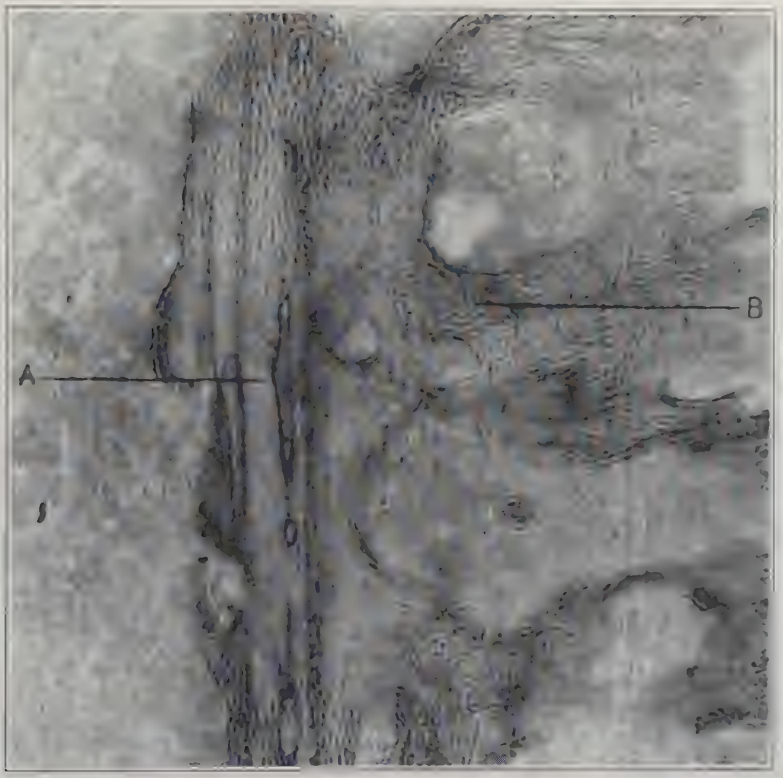


Fig. 1618.—High-power photomicrograph of rarefied cortex of bone shown in Fig. 1616: *B*, Necrotic bone surrounded by new living bone growing in the presence of an infection. It is reasonable to assume that as the infection subsides this bone would not be thrown off as a sequestrum, but would gradually become reorganized; *A*, necrotic bone with absence of bone nuclei; *B*, living subperiosteal bone.

hole was then made into the medullary canal, and the staphylococci introduced. This animal lived for two months with a persistent sinus. The *x*-ray showed a cortical sequestra with eburnation of the bone in its vicinity, tending to wall off the medullary canal.

It is true that in cases of non-union associated with a local osteomyelitis in compound fractures the complete removal of all sequestra is followed more or less promptly by union of the fracture and closure of any open wounds or sinuses.

CHAPTER XXX

UNUNITED FRACTURES

Meaning of non-union—Of delayed union—Time of union in fractures—Situations of non-union—Record of cases—Circumstances of non-union—Condition of bone fragments in non-union.

When one considers the various events at the site of a fracture and the orderliness and precision of the steps in the uninterrupted reparative process and the generally recognized factors favorable to complete union, it is not strange that at times the process of repair is interrupted, delayed, or is even entirely absent.

It is possible by the proper interpretation of carefully taken *x*-ray plates of the seat of fracture to determine whether only delayed union exists or whether a terminal condition of non-union is present.

In the former condition some evidence of bone activity will be manifest; in the latter condition all evidences of bone proliferation will be absent. Hence, in non-union it may be said that a fixed state (Henderson), or, as I like better to express it, a terminal condition exists. This terminal condition of a fracture—non-union—results from the inactivity of the process of repair. The final union of a fracture may be delayed some years after the original injury. Non-union of a fracture may exist as early as a very few months after the injury.

Time of Union of Uncomplicated Adult Fractures.—The time of union may vary within wide limits, dependent, of course, upon many conditions.

In cases of delayed union the process of repair may be stimulated to activity by certain methods of treatment (p. 961) and good union of the fracture secured.

In cases of non-union all these effective methods of treating delayed union will fail and will be found to be absolutely useless, the bone having ceased any attempt at repair. The bone is incapable of spontaneous union (Hey-Groves).

The usual method of determining the existence of non-union has been to exhaust all measures calculated to promote union even for many months. If the bone refuses to respond to this stimulation to activity, non-union is said to exist.

It is no longer necessary to delay and experiment as to whether union will take place between fractured bone ends. A careful study of the *x*-ray will usually determine the presence or absence of signs of the active reparative process.

Obviously, there may be instances in which the carefully taken *x*-ray will be unable to detect a beginning of the reparative process, and yet such a fracture may begin after a time to form new bone, thus becoming a case of

delayed rather than one of non-union. Such unrecognizable cases of potential non-union, however, will be rare. After all is said and done, the *x*-ray test is the best early test yet employed in determining whether a certain case is one of non-union or one of delayed union.

It is estimated that probably from 2 to 3 per cent. of all fractures in civil life are at present cases of non-union. Hey-Groves' estimate is 4 to 5 per cent., but this seems a bit high.

Of course, it is very important that the diagnosis of non-union should not be made if there is only delayed union. Non-union should not be mis-

Fig. 1619.—Note non-union of humerus with false joint and angulation forward. The line of fracture of the lower fragment is transverse. The line of fracture of the upper fragment is slightly oblique, a small thin fragment lies between the two main fragments (Waring and Milligan, British Journal of Surgery, vol. 9, p. 408).

Fig. 1620.—Shows non-union of fracture of the humerus; no contact of fragment ends, but considerable gap between fragments (Waring and Milligan, British Journal of Surgery, vol. 9, p. 418).

taken for delayed union. Delayed union will require expectant and non-operative methods of treatment, while non-union will require in most instances some operative procedure; or no operation upon the bone, but the permanent use of some form of retentive splint so carefully constructed as to make the situation endurable and useful. Consequently, a careful and exhaustive valuation of the conditions in each case will preclude the possibility of meddlesome surgery in delayed union.

Moreover, it will be wise in case of doubt to make a liberal, at least an adequate, time allowance for the development of all the corroborative evidence in favor of non-union, so as to avoid an error. No one with delayed

union cares to have an unnecessary operative procedure planned and carried out.

Common Situations of Non-union After Fracture.—*Humerus.*—Following a simple closed fracture of the shaft of the humerus in the middle and upper third of the bone non-union occurs more frequently than after fracture of any other bone. This happens even when the fragments are not displaced. It occurs especially after a slightly oblique or transverse fracture.

After an infected compound fracture of the humerus non-union is very likely to occur (see Fig. 1619).

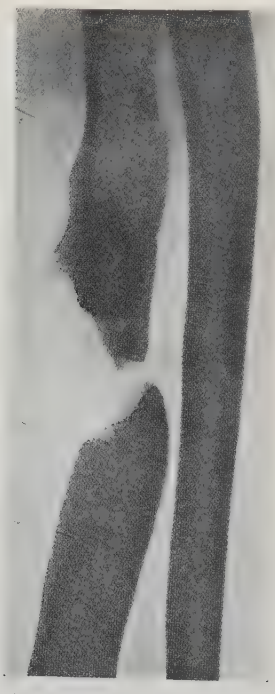


Fig. 1621.—Showing non-union of radius from the loss of bone between the fractured ends and want of apposition with longitudinal displacement and gap due to the intact parallel bone—the ulna (Waring and Milligan, British Journal of Surgery, vol. 9, p. 410).

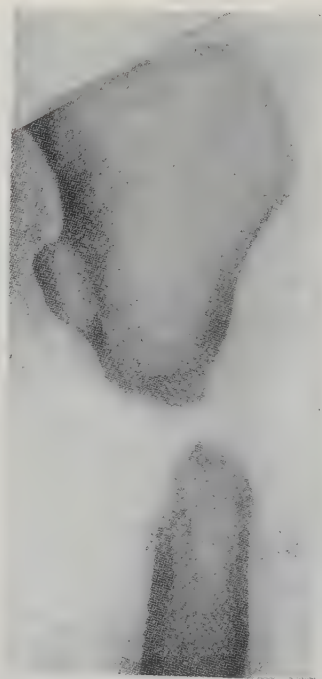


Fig. 1622.—Typical appearances in Roentgen ray of non-union of the upper third of femur (Waring and Milligan, British Journal of Surgery, vol. 9, p. 409).

Comminuted fractures at the middle of the humeral shaft are ordinarily followed by good union. Internal steel plates often keep the fragments apart, not in contact. This is unfavorable to union.

Gravity acting through the weight of the forearm may keep fragments of the fractured humerus apart and so favor non-union.

Radius and Ulna.—When the fracture is of both bones and transverse or very slightly oblique, and the bone ends are in apposition, there is almost always union of the fracture.

When the fracture is of one bone, without contact of bone ends, either because of the original trauma pushing one fragment away from the other,

or because of loss of substance from an operation or infection, the unfractured parallel bone prevents the damaged bone ends from coming together; they are held apart. Union cannot take place with such separation.

Femur.—The process of repair seems to be at its maximum in the femoral shaft.

Fractures in the lower third of the femur invariably are followed by solid union. Non-union in this situation is very unusual.

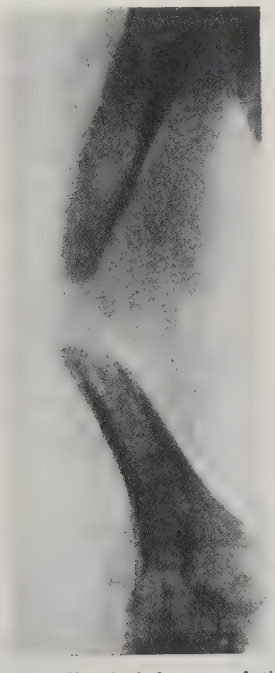


Fig. 1623.—Ununited fracture of the middle third of the humerus (A. P. Mitchell, British Journal of Surgery, vol. 10, p. 270).

Fig. 1624.—Non-union in lower third of humerus (A. P. Mitchell, British Journal of Surgery, vol. 10, p. 271).

Non-union occasionally occurs in the upper third of the shaft of the femur, and at the middle third also.

Non-union due to a steel plate holding fragments apart is less likely to follow in fractures of the femur, for the heavy thigh muscles tend to pull the fragments together.

Tibia.—Non-union following fracture of the lower third of the tibia is frequent. The process of repair is not very vigorous in the lower third of the tibia. The fracture is usually oblique. Non-union is due ordinarily to lack of contact of the bony fragments. Occasionally, when alignment and contact are perfect and with absence of any constitutional disease, union does not occur.

Non-union of the tibial shaft may occur even in children, in whom non-union is a rarity. The fibula holds the fragments of the fractured tibia apart.

Record of Non-union Cases.—Having to do with a case of non-union, the accompanying plan of assembling the facts of the case is helpful. If this scheme is followed no salient facts will be omitted.

Symptoms and Signs of Non-union.—In general, it may be said that clinically, if there is delayed or non-union at the seat of a fracture of a long bone, there will be found undue mobility at the fracture. The limb will feel weak. There will be tenderness at the site of fracture elicited by palpation. The function of the limb will be very decidedly under the normal.

A tabulated scheme of practical value in assembling the facts regarding a case of non-union following fracture (after Renfrew White):

A. *Inspection.* (Compare with sound side):
   1. Obvious deformity: shortening, angulation, rotation, lateral displacement.
   2. Swelling: its position, size, and shape.
   3. Redness of the skin.
   4. Wasting of muscles.
   5. Scars or sinuses.

B. *Palpation:*
   1. Tenderness.
   2. Heat.
   3. Thickening of the bone: amount, shape, position.
   4. Presence of abnormal mobility: level, degree, pain on movement; crepitus on movement.
   5. Palpable evidence of displacement.

C. *Measurements:*
   1. Length of bone or segments of limbs compared with other side.
   2. Circumference of limb at level of fracture.
   3. Other measurements in special regions fractured.

D. *Range of movements* of joints of limbs—active and passive.

E. *State of muscles* of limb:
   Wasting, spasm, paralysis, from nerve involvement: or absence of function; adaptive shortening; involvement in scar tissue adhesions.

F. *Complications:* Nerve.

G. *x-Ray examination:* Shape of bone ends; record of persistent displacements, longitudinal, lateral, angular, rotatory. The amount and position of the new bone formation.

H. *Record of deformity:* Sketch; cast; photograph.

CERTAIN CIRCUMSTANCES UNDER WHICH NON-UNION OF FRACTURES OCCURS

Types of Non-union.—1. All gross conditions seem ideal. 2. All gross conditions ideal, excepting use of non-absorbable fixation. 3. Separation of fragments by distraction. 4. Loss of bone. 5. Absence of contact, due to intact companion bone. 6. Fragments held apart by steel plate. 7. Lack of

contact due to position, angularity. 8. Muscular interposition. 9. Inadequate fixation. 10. Interference with the vascular supply. 11. An infection, chronic, with sequestration. 12. Frequent readjustments of fractures. 13. Too early locomotion, with weight bearing unprotected.

1. *Gross Conditions Seem Favorable to Union.*—It happens that the fractured bone fragments are in alignment. The ends of the fragments are in direct contact. The gross structure of the bone ends at the seat of fracture is normal. The line of fracture is transverse or only slightly oblique. Despite these conditions, however, bony union does not occur. Only fibrous tissue union exists. Such, at times, is the result of fracture in the middle of the humerus and in the lower third of the tibia.

2. *Following Non-absorbable Sutures.*—The conditions just outlined may exist; in addition, there may be certain changes in the bone ends. The fracture may have been operated upon with the use of wire, suture, or by steel plate. Still no bony union occurs.

3. *Too Great Traction.*—Such severe traction may be employed by the surgeon, or there may exist a distraction force (gravity, muscular contraction) of such degree as to separate the fragments of a fracture. A distinct gap exists between the fragments. Non-union of the fragments thus separated will result. This type of non-union is most often seen in patella and olecranon fractures, and in fractures of the humeral shaft. An actual loss of bone from the fracture site may leave a separation of the two fragments. A very slight gap between fragments will prevent bone repair. Small fragments, despite the presence of sepsis of a mild form, may maintain their vitality.

4. *Loss of Bone.*—During the war those compound fractures treated by removal of loose fragments from the site of fracture, irrespective of whether they were periosteally attached or not, were often followed by non-union. (See Treatment of Compound Fractures, p. 889.) There is no evidence of the reconstruction of the diaphysis of an adult bone after a considerable portion of it has been removed. The free removal of bone at the site of fracture almost inevitably leads to an ununited fracture (Hey-Groves).

5. *Absence of Contact Due to Intact Companion Bone.*—In the radius and ulna, when a loss of substance exists in one bone, the unbroken bone prevents by its very rigidity the approximation of the broken ends. When the humerus is ununited, its hanging at the side of the patient, unsupported, will through the action of gravity tend to keep the lower fragment away from and out of contact with the lower end of the upper fragment. If the tibia is broken and there is a loss of substance of the bone, the unfractured fibula may prevent the close approximation of the tibial fragments, thus favoring non-union.

6. *Steel Plate.*—The application of a steel plate to the fractured bone fragments may actually hold bone fragments apart and prevent union (Fig. 1661). Very many cases of non-union are associated with this form of maltreatment. A bone plate may be so misapplied as to hold fragments apart, and so applied as to maintain firm bony contact.

The application of a steel plate to facilitate the union of bone in a case of non-union is to be strongly deprecated, excepting, of course, in very special and appropriate cases.

A bone plate may hold bone ends rigidly, even in exact apposition, so that the ends of the fragments touch one another; but the ends of the bones may undergo slight absorption, thus causing a gap or interval ever so slight; this gap is unfilled and non-union is the result.

Possibly the suggestion to restrict the use of plates of steel to the large bones with ample blood-supply and which may require unusual force to hold them together, will diminish the cases of non-union from this cause.

Early open operation with the application of an internal non-absorbable splint (steel plate) may be a factor in non-union, due to the presence of the steel plate. Trout contends that experimental, theoretical, and clinical data all point to the presence of the plate as a factor in non-union.

Of 32 adult human cases of non-union, 70 per cent. had had previous early operation with steel plate. Of 211 cases of non-union occurring in Henderson's series, 66 per cent. had had previous early operation with steel plate. These figures are significant and suggestive.

See p. 784 for exact prohibitory effect of callous formation in the presence of a plate.

7. *Lack of Contact.*—Displacement due to shortening of the length of the limb only—where there is usually bony contact—is followed by union. It is the angularly placed fragments, without bony contact, with distance between fragments so great as to preclude gap-bridging, in which non-union occurs. This type of non-union occurs in the femoral shaft.

Poor, faulty, and inadequate initial treatment is the immediate occasion of such a result. The neglect of traction and disregard for the general alignment of the limbs are the contributing factors to shortening and lack of fragment contact.

8. *Muscle Interposition.*—Uninfected and closed transverse fractures result in non-union at times. Where there is a good alignment of fragments and end-to-end approximation associated with non-union, it is likely that there will be found interposition of muscle tissue.

The penetration of fragments through muscle masses or through fascia resulting in tissue interposition will result in non-union.

In civil life many of the forces—a fall from a height, an automobile accident, crushing by heavy weights, causing fracture of the shaft of the femur—produce a lateral or twisting displacement without open wounds. The fragments of the femur are displaced considerably. The muscle masses slip between the displaced ends and stay there. Non-union follows.

Properly applied traction resulting in an impossbility to reduce the fracture completely after two or three days' trial should arouse suspicion of muscle interposition (Kidner).

The long head of the biceps has been so caught between the oblique fragments of the humeral shaft fracture as to prove an obstacle to reduction as well as a delay to union.

9. *Inadequate fixation* of fragments is found to favor non-union, especially if it exists at the beginning of the process of repair. This is the time, at the beginning of union, when complete rest is most desirable; for great freedom of movement pulls on the soft callus, breaks it, and injures delicate capillary vessels. The result is fibrous tissue union, and possibly non-union.

There are four situations where great care must be used to keep fragments in suitable position and sufficiently immobilized:

(*a*) In the upper end of the humerus the bone becomes angulated outward. This can be prevented by keeping the arm in abduction.

Fig. 1625.—Case of non-union; ends freshened; intramedullary peg used as an internal splint, fresh fracture chips inserted from the iliac crest; union satisfactory (after A. P. Mitchell, British Journal of Surgery, vol. 10, p. 270).

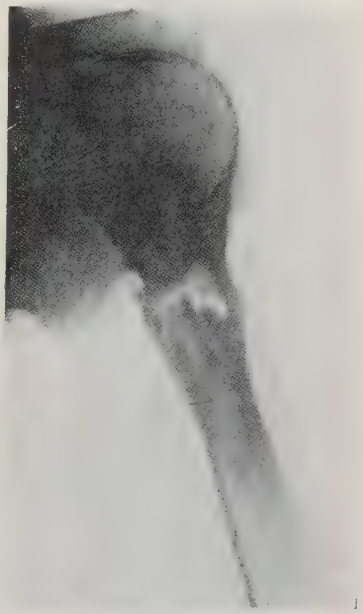


Fig. 1626.—Same case as that in Fig. 1625, two years subsequently. Function of the shoulder is excellent (after A. P. Mitchell, British Journal of Surgery, vol. 10, p. 270).

(*b*) In the radius there is always a tendency to pronation, which must be prevented by a splint from above the elbow to hold the arm supinated.

(*c*) At the upper end of the femur there is a tendency to angulation outward. After correcting this original deformity by flexion of thigh and by abduction of thigh, this position of abduction must be maintained by fixing a splint to the pelvis and lower extremity.

(*d*) There is a tendency for femoral shaft fractures to sag backward (see Figs. 999–1010). After suitably correcting this tendency and restoring the normal anterior bow of the femoral shaft, the corrected position must be adequately maintained while the patient is ambulating for several months (Hey-Groves).

10. *Interference with the vascular supply* to the bone near the seat of fracture is associated with non-union.

The periosteum has a distinct function in bone repair. That function is important even though the idea, once maintained, that the periosteum *per se* is the only source of bone formation, is no longer tenable. It is through the periosteum that a part of the vascular supply reaches the bone. When the periosteum is intact bony union is to be expected. When the periosteum is experimentally completely divided bony union is not to be expected. When the periosteum is slit bony union may or may not take place (Ely). In the treatment of fractures care must be taken to increase the blood-supply

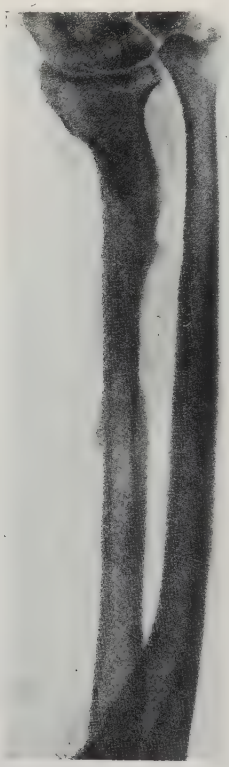


Fig. 1627.—Final result of tibial graft for non-union of the radius, two years after the operation. Canalization of the graft is almost complete (after A. P. Mitchell, British Journal of Surgery, vol. 10, p. 267).

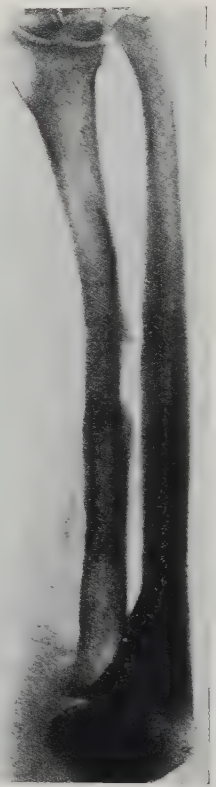


Fig. 1628.—Final result of tibial graft for non-union of radius, three years after the operation. Note the complete canalization of the graft (see Fig. 1627) (after A. P. Mitchell, British Journal of Surgery, vol. 10, p. 267).

(Bancroft). Non-union may be associated with damage to the nutrient vessel (Eliason). The separation of the soft tissues from the periosteum leads to an impairment of the periosteal blood-supply. A destruction of the periosteal blood-supply leads to non-union of fractures (Kolodny).

If one recalls the appearance of a limb in which non-union is found, after an immobilizing plaster splint has been removed, it will be seen that the vascularity of the part has been interfered with and probably is a factor in the non-union. The limb is shrivelled; the skin is dry, pale, and wrinkled.

The bony prominences are all very noticeable. The limb is cool. The musculature is atrophied, small, functionally inactive. Is it surprising that under these conditions the bony tissue is equally inactive and slow? Compressed by bandages and splints, with the possibility of a rupture of certain vessels having occurred going to the distal fragment the limit is not normal.

Moreover, the fact must always be kept in mind that with bandages circularly applied in making a plaster-of-Paris splint there may be failure to secure the proper length of the limb; hence overlapping of the fragments may exist, with which deformity non-union is at times associated.

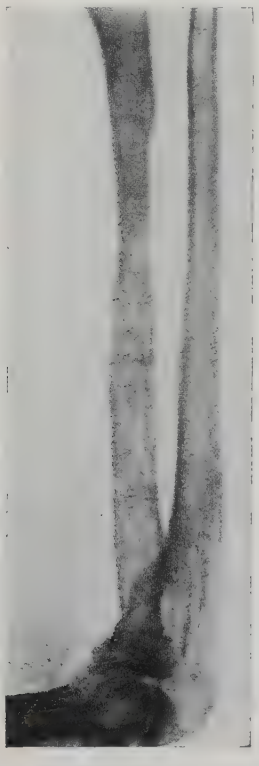


Fig. 1629.—Grafting operation done for non-union of radius. Medullary canal completely reformed. Massive tibial graft used (after A. P. Mitchell, British Journal of Surgery, vol. 10, p. 267).

Fig. 1630.—Massive lateral tibial graft united strongly with host bone at both ends. Appearance by Roentgen-ray record seven weeks after grafting operation (after A. P. Mitchell, British Journal of Surgery, vol. 10, p. 259).

11. An *infection* at the seat of fracture, while acute, will retard the reparative process in the bone; but if this infection is controlled as it subsides, the process of repair will be resumed and possibly even accelerated. Late union of the bones does occur in the presence of sepsis and is, indeed, simply a part of the phenomenon of union by granulation tissue (Hey-Groves).

Actual necrosis of the bone at the seat of fracture, whether mechanically separated from its blood-supply or because of sepsis, will cause delay or

failure of union (Hey-Groves). This is rare. If the necrotic bone is removed, the probability is that spontaneous union will eventually occur and no grafting operation will be necessary.

12. *Frequent Readjustments of Fractures.*—Misdirected zeal on the part of the surgeon in civil practice will often result in unfavorable conditions for repair. Splints are removed early, the bony fragments are moved, "tested," to determine whether union has occurred. This investigation of the frac-

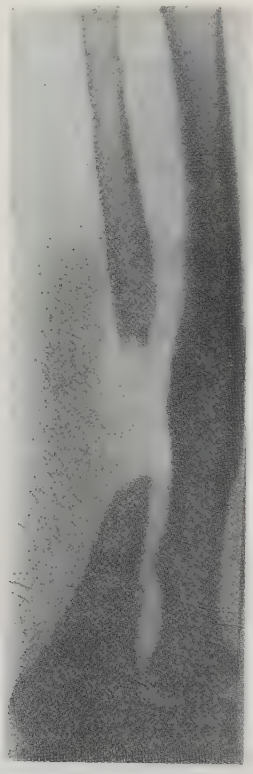


Fig. 1631.—Fracture of middle third of ulna. Appearances before final graft operation. History of case, viz., sequestrectomy. Bone-grafting. Sepsis. Graft removed. Second grafting from tibia. Sepsis mild. Graft lived. The figure shows the condition five months after operation (after A. P. Mitchell, British Journal of Surgery, vol. 10, p. 261).

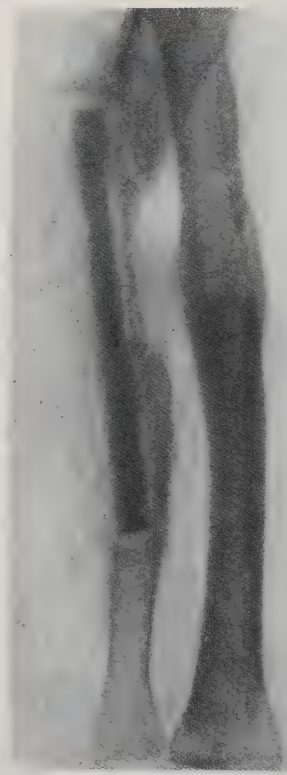


Fig. 1632.—Condition five months following last operation of grafting. Note callus from host bone and appearing along the graft (see Fig. 1631) (after A. P. Mitchell, British Journal of Surgery, vol. 10, 261).

ture is apt to take place at the very time when absolute immobilization is most desirable. Frequent inspection and examination of the fracture, resulting in twisting and crushing the parts, has a tendency to injure tissues and hinder the process of repair. An impatient surgeon may do much harm to a fracture, especially in this early stage. I believe that gentleness, the absence of great trauma in the handling of a fracture, favors and accelerates the process of repair in bone to a far greater degree even than is the case in an ordinary extensive wound of the soft parts.

13. *Too Early Locomotion.*—It is known that too early continuous weight bearing should not be attempted in fractures of the lower extremity for fear of bending at the seat of fracture. A femoral shaft fracture would bend outward and cause a bow-leg. A femoral neck fracture might yield a coxa vara. An ankle fracture might be followed by a flat-foot.

It is also possible that non-union or a fibrous union may result from very early use of the part, not sufficient and not long enough immobility having been maintained to secure union.

Condition of Bone Fragments in Non-union.—The tissues surrounding the fracture are matted together and adherent to themselves and to the bone

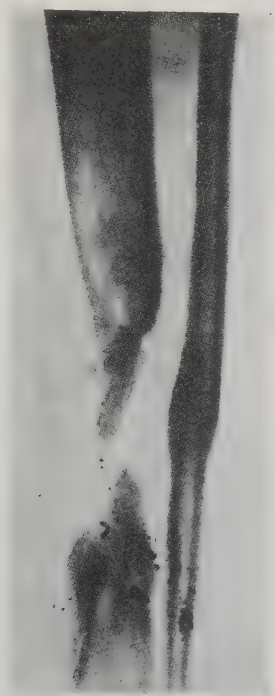


Fig. 1633.—Non-union of tibia. Transverse fracture of fibula at opposite point to be grafted (after A. P. Mitchell, British Journal of Surgery, vol. 10, p. 272).

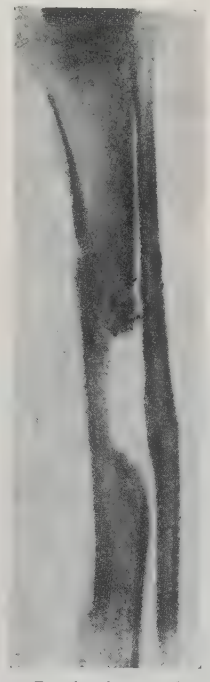


Fig. 1634.—Result six months after grafting operation of single massive graft. Strong bony union. Function of leg good. Note that the graft is firmly united to each fragment (see Fig. 1633) (after A. P. Mitchell, British Journal of Surgery, vol. 10, p. 273).

(Waring and Milligan). Fibrous tissue may be found occupying the space between the broken ends. In this fibrous tissue about the ends of the bone may be latent sepsis. All these conditions are inimicable to bone formation.

Infected fractures which do not unite, and in certain other non-union cases, the bone ends are dense, hard, brittle, and atrophied. The ends are covered by firm fibrous tissue having in it no bone-forming elements. The periosteum may be replaced by fibrous tissue and is very adherent to the bone. The medullary canal is closed by connective tissue or bone. The bone ends are often tapered and conical.

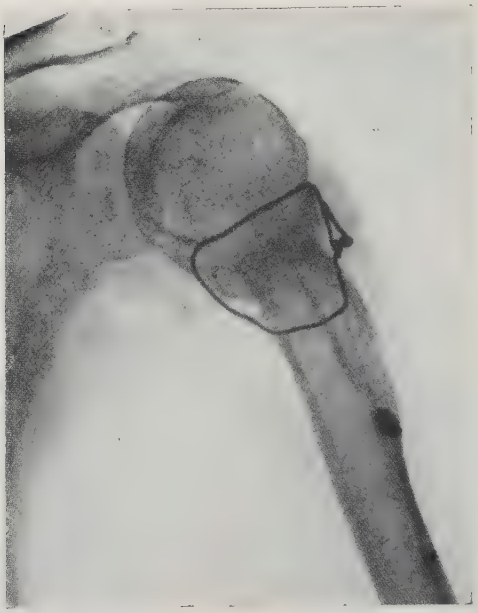


Fig. 1635.—Case of non-union of humerus in upper third. Sclerosed bone removed; distal fragment impacted into proximal fragment; fixation secured and maintained by wire suture; strong union occurred; function of shoulder excellent (after A. P. Mitchell, British Journal of Surgery, vol. 10, p. 270).

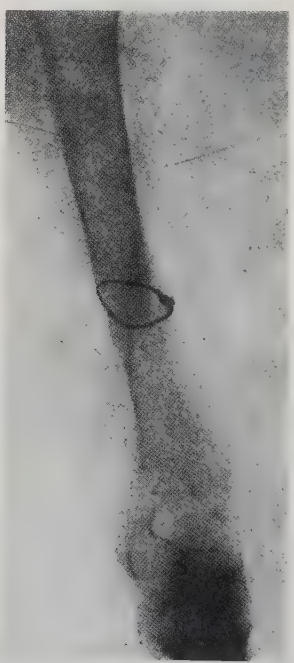


Fig. 1636.—Result of step cut operation eight months after (after A. P. Mitchell, British Journal of Surgery, vol. 10, p. 270).

Fig. 1637.—Humerus united over a short ivory peg with a successful result (after Hey-Groves, British Journal of Surgery, vol. 6, p. 214).

CHAPTER XXXI

UNUNITED FRACTURES (*Continued*)

Treatment of delayed and non-union without bone-grafting—General causes of delayed union—Clinical factors in non-union—Work of Petersen—Calcium and phosphorus content of blood—Prevention of non-union.

Treatment of Non-union or Delayed Union Without Bone-grafting.—It is sane and wise to treat evidently delayed union by methods other than bone-grafting and major operative procedures. If the delayed union cases were adequately treated there would result fewer non-union cases (Jones-Murphy).

In cases in which there is no bony contact and dense fibrous tissue exists, and possibly there is present a small infected focus, where the periosteum is literally replaced by fibrous tissue, the medullary canal is closed, the bone ends are rounded and conical, dense, hard, and non-vascular, the surrounding soft tissues are adherent to the bone and to each other—in such cases there is no use trying palliative and non-grafting methods, for under these conditions there are no active factors for repair present to be stimulated.

Fig. 1638.—Illustrating the constriction bands placed above and below a fracture of the right humerus. See text for application for securing edema and stimulation of repair.

If an infection is present actively or potentially at the seat of non-union, see p. 978 for suggestions as to the best procedure previous to a grafting operation. Briefly stated, one may operate at once, or delay operation for a certain time, or do the first step of a two-stage operation. (See p. 975 for a discussion of a choice of these methods.)

Stimulation to the formation of callus has been tried in various ways. The application of a carefully fitted splint, if the lower extremity is involved, which, while protecting from angular deformity, allows of a certain amount of locomotion contact, will often be followed by gradual stiffening and eventually firm union. The value of this method lies not so much in the local irritation at the site of fracture as in the strain put on the longitudinal axis of the bone (Speed). The bone will respond to the normal physiological demands put upon it (Wolff).

Passive congestion as advocated by Bier and by Thomas may be tried. A tourniquet of rubber tubing (Fig. 1638) may be applied above and below the seat of fracture (Thomas). A very definite and local congestion may be secured by this method.

A flat rubber band tourniquet (Bier) may be applied above the fracture site. This is applicable especially to the forearm and leg bones and produces a satisfactory congestion.

In using either of these methods, of course, immobilizing splints are employed to keep the fragments rigid. The tourniquet is placed tightly enough to secure considerable swelling and circulatory stasis about the fracture. This constriction must be used intelligently and cautiously. The time it is applied may be gradually lengthened until it is used for from two to three hours intermittently during the day. In two or three weeks considerable callus may be expected to be developed in favorable cases.

With the limb elevated, a light plaster-of-Paris splint (circular bandage) may be applied to the limb for fixation purposes. A window is cut opposite the fracture site, the limb is lowered and used. Local edema of the region uncovered by the window will result, and a consequent stimulation is supposed to occur at the seat of non-union.

The indolent, almost painless, non-union case may be treated by a continuation of trauma and damming. Under an anesthetic the soft callus (fibrous) is broken and the fractured ends turned toward the skin and carefully beaten with a mallet, a pulley is applied (Hawley table) to the limb—as much length as possible gained by traction—a Thomas splint applied, and traction maintained. Damming is used by the application of rubber tubing tourniquets (Fig. 1638) above and below the site of fracture, at first for twenty minutes each day, until they can be borne for several hours at a time. The tourniquets should be placed tightly enough to secure considerable swelling and stasis.

Injection of various materials about the bone ends in ununited delayed union cases is followed by doubtful benefit. The injection of blood from the patient, of various emulsions of bone-marrow, or of calcium phosphate and calcium carbonate with sterile liquid vaselin, of bone filings, of ground bone—all have been tried and advocated. I think they should be avoided as inefficient.

I have been impressed by rigid immobility as a factor in delayed union. Hey-Groves calls attention, in this connection, to the rôle of movement in the treatment of fractures advocated by Lucas-Championnerè, saying that movement must be regulated by three conditions: They must be (1) painless, and they must not (2) tend to displace the fragments from one another, or (3) change the alignment of the bone. The carrying out of these three conditions will not be incompatible with suitably prolonged immobilization and early active and passive motion (p. 907).

General Causes of Delayed Union and Non-union.—There is, as far as I am able to determine, no positive proof that the following diseases and conditions are important in the causation of non-union of bone: pregnancy and the period of lactation, malaria, severe hemorrhages, starvation, any of the so-called cachexias, diseases of the central nervous system (general paralysis, tabes), diseases of the ductless glands, nephritis, acute febrile diseases, old age as such.

It is possible that the repair of fractures may be a bit more slow under the above conditions, but that any one of the above conditions is an adequate cause in itself of non-union is yet unproved.

There is probably only one general disease which has a marked influence on bone repair, which may be reckoned with as a hindering force in cases of delayed union, and that is syphilis. The clinical evidence is certainly unmistakably sure that, apart from local factors, syphilis influences the repair of bone. There are cases of closed fracture with few other important local causative conditions present which have resisted ordinary carefully con-

Fig. 1639.—Dog No. 1 on regular diet. Plate taken at time of fracture. Calcium 10, phosphorus 5.8, product 58 (Petersen, Johns Hopkins Hospital Bulletin, November, 1924).

ducted fracture treatment, and which fail to unite. The Wassermann test is found to be strongly positive. Antiluetic treatment is judiciously instituted. Within a few days the reparative processes are under way and union of the fragments advances to solid bone. Such clinical experiences are to be numbered by the score, and whereas I am unaware of any direct confirmatory findings of the Spirochætæ pallida at the fracture site, still the clinical evidence is convincing that syphilis at times is a potent factor in delaying the reparative processes of bone. It is true also that in the presence of syphilis closed fractures do unite without antiluetic treatment.

Clinical Factors in Non-union.—In view of the remarkably clear and valuable experimental and clinical work of Petersen,[1] it may be said that the general deficiency in the calcium and phosphorus serum content of the blood is at times an adequate factor in delayed and non-union. Here is the place to record this important contribution to bone repair.

As stated elsewhere (see p. 935), the following theory of bone chemistry seems of real practical value. There probably is no definite bone-producing cell. The osteoblast, whatever its origin, may elaborate that which assists in the deposition of lime salts. The complex salt, calcium carbonophosphate,

Fig. 1640.—Dog No. 1 on adequate diet. Plate taken four weeks after fracture. Calcium 10.3, phosphorus 5.6, product 57.7. Fracture healed solidly (Petersen).

carried as such in the blood, is precipitated in the future bony matrix by a change in the carbon dioxid content of the tissue, and after deposition is finally converted into two components, calcium carbonate and tertiary calcium phosphate. Calcification, according to Wells, occurs in dead tissue, whereas ossification takes place in living tissue. Exactly how these bone salts are deposited or added in the process of repair is, of course, as yet unknown.

Non-union is especially common after osteotomy for bow-legs, rachitic in origin. A study of the *x*-rays of rachitic children, in whom single or mul-

[1] The Journal of Bone and Joint Surgery, October, 1924.

tiple fractures occurred, revealed the fact that when the bones showed a healing of the rachitic condition, the coexisting fractures also showed healing. No healing of the fracture was observed until the rachitic conditions showed improvement.

The use of calcium by certain clinicians and of yellow phosphorus by Phemister in treating non-union efficaciously also is suggestive. It was found by Petersen in 9 cases of ununited fracture occurring in adults that a low calcium and phosphorus serum content existed. Those having a low phosphorus content were placed on a diet rich in phosphorus. Those having a low cal-

Fig. 1641.—Dog No. 2 on diet. Plate taken at time of fracture. Calcium 8.9, phosphorus 3.6, product 32. (Petersen).

cium content were placed on a diet rich in calcium. Of 8 patients treated, 7 went on to solid bony union; one is still ununited. It required treatment for about three weeks before the blood-serum examination showed an increase in the low salt.

As a control to these cases a similar number of apparently normal persons with fractures were studied, and the calcium and phosphorus serum content determined at the time of the fracture and when union was completed, as well as at intervals between.

During the process of union there was little or no increase in the calcium or phosphorus of the blood-serum.

In many cases of ununited fractures there is an underlying basis, a constitutional disturbance responsible for the condition, demonstrable as a deficiency in the inorganic bone-forming elements of the blood. This deficiency shows itself as either a low phosphorus or a low calcium, in most instances the former. In those patients presenting a low phosphorus there is usually an abundant callus, but no calcification; whereas, those patients with low calcium usually show little or no callus.

The calcium and the phosphorus was determined and expressed in milligrams per 100 c.c. of serum. These determinations were multiplied together

Fig. 1642.—Dog No. 2 on inadequate diet. Plate taken four weeks after fracture. Calcium 9, phosphorus 3.2, product 28.8. Fracture ununited. No union after three months (Petersen).

and the product spoken of as the "inorganic calcium and phosphorus content" for that individual. A calcium of 10.4 and phosphorus of 4 would yield a product of 41.6.

It was found that no healing of the fracture takes place when the inorganic constituents calcium and phosphorus are so reduced that the product of these elements is less than 30; little healing takes place between 30 and 35; active healing results with a product between 35 and 40.

Patients with ununited fractures in whom there is a deficiency of one or the other of these elements will, when the deficiency is compensated, go on to healing.

The *experimental work on dogs* is so valuable, also done by Petersen,[1] that I likewise quote freely from it the salient points.

Fig. 1643.—Dog No. 4 on inadequate diet. Plate taken four weeks after fracture. Calcium 10, phosphorus 2.4, product 24. No union (Petersen).

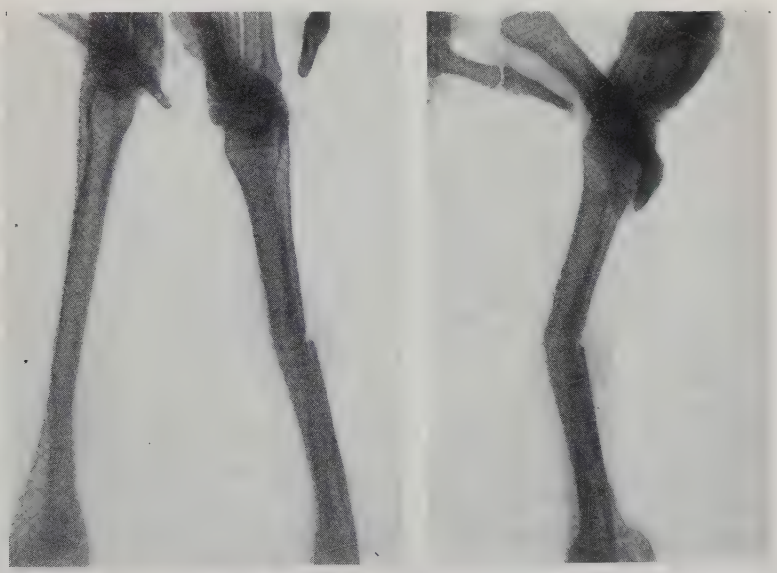


Fig. 1644.—Dog No. 7 on inadequate diet. Plate taken four weeks after fracture. Calcium 9.8, phosphorus 2.7, product 26.5. No union (Petersen).

It was found that in the clinical study of non-union in the human the optimal product of healing in normal fractures was between 35 and 40,

[1] Johns Hopkins Hospital Bulletin, November, 1924.

whereas in many patients with an ununited fracture the product was below 30. This latter product was concluded to be entirely inadequate for bone healing.

The method of procedure in the conduct of these experiments was as follows: First, to determine the normal calcium and phosphorus content in the serum of dogs; next, to diet these animals, calculating to reduce the phosphorus content of the serum; and finally, to produce fractures and observe healing.

Fig. 1645.—Dog No. 4 on diet. Plate taken four weeks after fracture. Calcium 10, phosphours 2.4, product. 24. No union (Petersen).

Conclusions from the dog experiments:

1. In the healing of fractures a definite relationship exists between the concentration of the inorganic bone-forming elements in the serum and the rate of repair.

2. If the phosphorus content of the blood-serum of the dog is reduced by diet to such a degree that the product of the calcium and phosphorus is less than 30, fractures will not unite.

3. If the phosphorus and calcium-phosphorus product are again raised to their normal dog level, the fractured bones will unite.

Consequently, we have in the above carefully observed human cases of fracture combined with the equally carefully conducted animal experiments

satisfactory evidence of the significance and importance of these general factors in bony union. Confirmatory evidence of these data will be awaited with great interest. (See Chapter XXIX.)

To Prevent Non-union.—In approaching the treatment of any and of every fractured bone, therefore, it is important that the surgeon should so carefully safeguard the treatment instituted that he may preclude the possibility of any deviation from the normal healing, so that delayed union and non-union may not occur. A carefully conducted treatment will minimize

Fig. 1646.—Dog No. 4 on adequate diet. Control animal to Dog No. 4. Plate taken four weeks after fracture. Calcium 10.2, phosphorus 5.7, product 58.1. Union solid (Petersen, Johns Hopkins Bulletin, November, 1924).

the liability to non-union. The surgeon should check up his treatment in its various steps. He should inspect each step somewhat as follows:

1. Is the fracture well reduced? *x*-Rays to be taken in two planes, and when possible and desirable stereoscopic *x*-rays should be had. "Well reduced" will mean that there is (*a*) good alignment of the fragments; (*b*) good length of the limbs; and (*c*) end-to-end apposition when possible.

2. Is the immobilization of the part satisfactory? Is there a minimum amount of motion at the seat of fracture?

3. Is the circulation of the part good?

If these three questions can be answered affirmatively, there is a minimum likelihood that delayed union or non-union will occur.

When the surgeon is required to care for a fracture of that bone where non-union is common, it is important that he have actively in mind this possibility, so that, being forewarned, he may be forearmed against this serious condition.

In connection with the constitutional or general cause of non-union it must not be lost sight of that certain experiments prove beyond a reasonable doubt that endocrine disturbances may play a prominent rôle in the suppression of regenerative processes of bone (Kolodny).

CHAPTER XXXII

BONE-GRAFTING

SECTION A

Historical outline—Histological changes after bone-grafting—Rôle of the periosteum—Fate of the transplant—Effect of steel plate on bone repair—Contraindications to bone-grafting—Operation of bone-grafting—Importance of a careful technic—Indications for bone-grafting—Success in bone-grafting.

Historical Summary.—*Ollier* in 1858 established the fact that bone could be implanted in the body and not be extruded. He believed that the entire graft remained viable. He believed that the periosteum was important in maintaining the life of the graft.

Radzimowsky and *Bonome* and *Barth* presented facts which seemed to prove that the graft disappears eventually and is replaced by new bone. The source of the new bone is from the surrounding osteogenetic tissue.

Axhausen in 1908 maintained that portions of the periosteum remained viable and produced new bone. When the transplant had a function to perform, the activity of the periosteum reached its greatest degree. The bone-graft disappears and is replaced.

Macewen believed that the new bone comes from the bone osteoblasts of the transplant and that the periosteum is a limiting membrane only.

Baschkirzew, *Petrow*, *Bancroft*, *Neuhof*, and *Gallie* believe that periosteum and bone-marrow are not essential for the regeneration of bone in a bone transplant. The chief source of the new bone is the layer of tissue of the host surrounding the transplant.

The Histological Changes After Bone-grafting.—Experimental study of bone transplants. (Chapter XXIX.)

The facts and statements contained in this section are essentially taken from the Surgical Monograph of Harold Neuhof on The Transplantation of Tissues, D. Appleton & Co., 1923. This monograph seems to me to present a sane and clear view of the present state of knowledge on this subject.

Bone-grafting.—The liberation of substances from the slowly disintegrating graft is a physicochemical stimulus resulting in the metaplastic formation of bone tissue from the adjacent connective tissue of the host. The bone cells of the graft die more or less rapidly, depending on their distance from the source of nourishment in the host.

Periosteum and endosteum undergo at least partial necrosis. There is no conclusive evidence that bone is derived from the periosteum or the endosteum of the graft. All evidence points away from periosteum as a source of bone formation. The periosteum is not osteogenic. The presence or absence of the periosteum in autogenous bone transplants has no decided influence on the activity of the subperiosteal osteoblasts (Gallie and Robertson).

The periosteum plays, however, an important rôle in bone transplantation. Primary adhesion of the tissues of the host occurs most readily in the presence of periosteum. Periosteally covered bone-grafts heal in place most promptly. Periosteally covered grafts tend to show slower absorption phenomena. The periosteum is of great importance because of its control of the circulation throughout living bone.

New bone formation in and about a graft is somewhat dependent upon stress and strain upon the graft (Neuhof).

The histological picture of all writers and investigators is the same after bone-grafting. Controversies have arisen in the interpretation of the findings.

Changes Taking Place in the Transplant.—The *first union* of the transplant with the surrounding tissue occurs by a fibrinous exudate. The latter becomes organized, a layer of new connective tissue being laid down.

The *degeneration of the graft* and its replacement begins at this early stage.

Union of the graft with the adjacent bone is by means of callus derived from the host. After three weeks the muscle and other tissues close to the transplant become rapidly adherent to the surface of the graft.

Union with surrounding tissues occurs more rapidly if the transplant is covered by periosteum than without it. After six days, however, no difference is noticeable in the vascularization with or without periosteum.

Evidence of the *absorption of the graft* appears in the nuclear changes of the bone cells, in the lacunar absorption from the surface, from the haversian canals, and from marrow spaces of the graft. The process of substitution goes on along with the process of absorption. Connective-tissue cells and young blood-vessels invade the bone-marrow, haversian canals, so that after about eight days the transplant is surrounded and permeated by a vascular young connective tissue.

Calcification begins about the fifth day in the richly cellular connective tissue. Osteoblastic-like cells appear. Bone lamellæ appear on the surface and about the haversian canals of the graft framework—skeleton. New bone formation keeps pace pretty constantly with the absorption of the dead bone of the graft. The vessels of the graft disappear, as does the osseous portion. The marrow of the graft shows evidence of degeneration after about seven days and replacement by a connective tissue which becomes very massive and rich in blood-vessels. After five weeks the replacement of the contents in the marrow space is advanced.

No single element of a bone-graft is essential for successful transplantation. The bone-marrow is perhaps of minor importance. Persistent viability and an osteogenetic process originating in the periosteum have not been proved. The practical importance of transplanting overlying periosteum with bone lies in the fact that early union of the graft with the surrounding tissue occurs and the process of orderly replacement of the transplant by bone is thereby invited and favored.

From the histological findings, it is to be concluded that a bone transplant dies as a whole. Some elements necrose more slowly than others. This varying duration of viability of the graft influences the rate of the replacement

phenomena and is thus a factor in obviating too rapid absorption of the graft itself. The clinical importance of this fact is obvious (Neuhof).

The graft is a passive regulator of the rate of repair.

The presence of an autogenous graft may not only be a regulator of repair but a distinct stimulator of the latent reparative processes in the host tissues. This is evident from the histological experimental studies following grafted fractures of bone. Non-union conditions have actually prevented the factors entering into the processes of repair from functioning.

Inert substances, such as bone plates, serve one purpose only, the fixation of the fracture. The autogenous bone transplant introduces into the situation a stimulus to osteogenesis which is absent in the ordinary ununited fracture. The steel bone plate supplies a temporary fixation and nothing more. Associated with the presence of the steel plate is often and usually a prohibitory influence on bone production where the plate lies.

A bone transplant is not a foreign substance. It does not require later removal. It does not invite rarefaction of adjacent bone. A bone-grafting is therefore ideal for the treatment of non-union and pseudarthrosis.

Contraindications to Bone-grafting.—The presence of an infection at the site of the proposed graft is the absolute contraindication to an autogenous grafting operation. An infection of the bed from which the graft is to be removed is also a contraindication. The failure of a graft because of infection may prove to be a real disaster and necessitate serious consequences, not only at the situation of the graft but at the place from which the autogenous graft was secured.

Whenever satisfactory results may be expected by the use of ordinary surgical measures, bone-grafting is contraindicated (Neuhof). Bone-grafting should be reserved for the times when it is very clearly indicated.

The Operation of Bone-grafting.—The technic of the operation of bone-grafting has an important influence on the results that are obtained. Greater surgical skill and judgment are required in the performance of a successful bone-graft than is required in almost any other surgical procedure. In order that the ultimate success of a bone transplant may be assured, it is essential that the surgeon understand the principles which underlie the transplanting of bone tissue. The operation of the transplantation of bone is not lightly to be undertaken by any tyro in surgery. The processes involved are recognized as extremely complicated even if not entirely understood. The successful transplanting of bone tissue requires as thorough an understanding as is practicable of these fundamental processes (Neuhof).

Because susceptibility to external influences is one of the striking characteristics of a transplant, a fastidious technic is one of the most essential features of successful tissue transplantation (Neuhof).

Grafting is a laboratory experiment and requires meticulous care.

Indications for the Performance of a Bone-grafting Operation:

In non-union of a fracture of bone.

Sometimes in long delayed union of bone.

To replace the loss of bone in the long bone of a limb.

In the inferior maxilla where there is non-union or loss of substance.

Bone-grafting is at present in my judgment contraindicated as a routine in the treatment of recent fractures. It is applicable to but few fractures of the neck of the femur. It is not applicable to fractures of the patella.

Success in Bone-grafting.—A successful bone-grafting operation will depend upon its employment under necessary conditions, where no other operation could be performed, with the persistence of the graft until it is satisfactorily replaced by the host tissues.

Autotransplantation of living periosteally covered bone will meet the greatest success.

CHAPTER XXXIII

BONE-GRAFTING (*Continued*)

SECTION B

General—What the surgeon should know—Injuries associated with fracture—Preoperative bone-grafting treatment—Ununited fractures without infection—Ununited fractures with infection—Is latent infection present?—How long delay grafting operation—Two-stage bone-grafting operation: First stage, Second stage.

General.—The transplantation of bone to the seat of an ununited fracture forms one of the most brilliantly successful operations in surgery. In any given case of non-union the surgeon should be familiar with (*a*) the total damage to the part, (*b*) both the general and local causes of non-union after fracture, (*c*) the exact condition of the tissues at the seat of fracture, (*d*) the events following the transplantation of bone tissue under both normal and adverse circumstances. Informed and armed with these facts, the surgeon will be prepared to undertake intelligently and successfully the very technically important operation of bone-grafting.

The injury which caused the original fracture in a severe accident has often done very great damage to other parts besides the bone. Muscles may have been torn away or destroyed. A nerve may have been injured. Fractures of the tibia may be associated with serious changes in the tibialis anticus muscle. There may be a loss of the extensors of the thumb in cases of non-union of the lower portion of the radius. The forearm and hand would be useless without the power of extension in the thumb. There may be very marked limitation of pronation and supination of the forearm, the fingers may be stiff. In non-union of the radius there may be a great deviation of the hand to the radial side. The several joints of an extremity may be stiff following injury.

Many of these associated conditions can be remedied in whole or in part previous to a contemplated bone plastic. A carefully planned preplastic-operative treatment will undoubtedly improve the whole extremity, including the joints. Such treatment would include minor operations of tenotomy, the stretching of tendons, improving the position of the parts, stimulation of the nutrition of the skin, the partial removal of fascial adhesions, excision of cicatrices, massage, electrical treatment, active and passive movements, and hydrotherapy in its various forms.

A fractured limb treated from the outset by mobilization and massage, treated as a complicated machine, is fit and ready to perform its various functions the moment union in the bone is adequate to resist strain (Jones). This is even more true when a limb has been out of commission for some weeks or months without union of the fractured bone. Preparatory pre-

operative treatment of ununited fractures certainly will well repay every effort in this direction.

The long duration of non-union is rarely a contraindication to an operation for promotion of union (Beresford).

Ununited Fractures Without Infection.—*Aseptic Cases. Closed Fractures.*—In fractures that have never been infected where there is non-union of the fragments, the line of fracture is ordinarily transverse or slightly oblique. Non-union almost never follows in greatly comminuted or impacted fractures. The ends of the ununited fragments appear in the *x*-ray about normal, they are in apposition or nearly so, a little fibrous tissue lies between them, the alignment of the limb is excellent (Fig. 1647).

Under the above conditions, the simplest type of operation will be carried out in about the following steps:

1. An exposure of the seat of fracture by suitable incision.
2. The removal of the adventitious intervening fibrous tissue.
3. The freshening of the bony surfaces.
4. The drilling of the bone ends to open up bone tissue.
5. The opening of the medullary canal, being sure that its passage is free for vascularization purposes.
6. The bringing the refreshed fragments into contact end to end, if possible, or side to side if necessary, securing bony contact.
7. Holding the bone fragments in tight and snug apposition by absorbable suture if possible, or by bolt and nut or screw or steel plate and screws if compelled to.
8. Immobilization of the limb following the operation in a dressing or splint that will securely and adequately hold the parts immobile.

See p. 980 for details of the above simple operation for non-union.

Ununited Fractures with Infection.—Infected fractures fall into two groups: Those closed simple fractures requiring operation and accidentally infected by the surgeon, which have healed. Those compound fractures infected at the time of the injury, which have healed.

It is at present with these at one time open but healed fractures that we are concerned—the healed compound fracture, the great war fracture, the less virulently infected civil compound fracture which has healed.

The only absolute contraindication to bone-grafting is the presence of infection. A failure of the graft may be a disaster, and likewise any infection in the area from which the graft was removed may be a very serious matter. Therefore, as Neuhof says, the indication for any bone-grafting operation should always be carefully reviewed with the possibility of infection in mind.

The likelihood of there being in any healed compound fracture potential or latent infection will depend in large degree upon the character, extent, duration, and result of the original infection.

An extensive bone damage with slowly healed sinuses will preserve an infection in latent form much longer than a fracture associated with an incised clean-cut compound wound, which heals ordinarily so readily or with

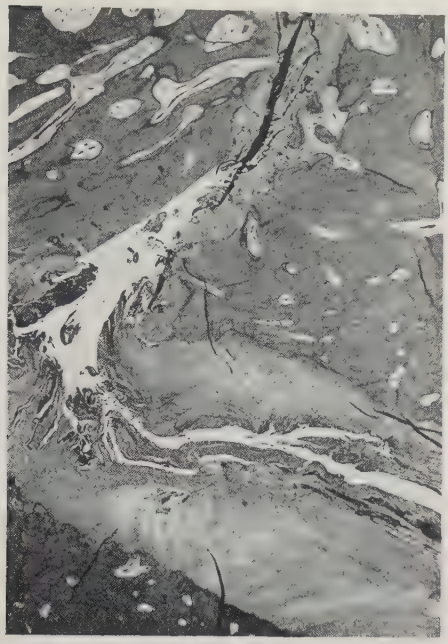


Fig. 1647.—Case I. Non-union of a fracture of the humerus of seven years' duration. Note dense fibrous tissue between ends of bone fragments (Allison).

Fig. 1648.—Case II. Non-union following fracture of the tibia of three years' duration. Comparing the appearances with those of Fig. 1647, the fibrous tissue is seen to be less dense and more cellular (Allison).

slight delay. Whereas a graft may live and function in the presence of a mild infection, it is likely to be extruded.

The utmost care must be taken not to operate in the presence of infection. Sepsis then at all costs must be avoided.

If operation is done in a potentially septic closed compound fracture, the septic process will be started up afresh and this infection may become so virulent as to cause serious harm.

Consequently, in every case of non-union previously septic the question arises: (1) How can one determine whether a closed wound is potentially septic? (2) Given a potentially septic case, how long will it be wise to postpone a grafting operation?

The development of local tenderness of the cicatrix of an old compound fracture following massage and gentle percussion of the cicatrix suggests a latent infection beneath. But the surest way of detecting a latent infection is by operating to clear away fibrous tissue as a first step to a plastic procedure.

Ununited fractures with previous infection fall into two groups from the point of view of treatment:

1. That group in which the surgeon will delay a plastic operation for from six months to one year, hoping that any mild latent infection will meantime have completely disappeared.

2. That group in which the surgeon will operate in two stages.

Cases in the first group are ordinarily those in which the original infection was mild. The previous infection having been mild and months having been allowed to elapse since it was active, the surgeon may proceed safely with the bone-grafting operation, without being fearful of lighting up the original infection.

Cases in the second group, or the two-stage group, are those in which the original infection was long continued and virulent.

Bone-grafting.—The two-stage operation, following infection.

Preparatory or First Stage.—All easily accessible adventitious fibrous tissue is removed by sharp knife dissection from the bone-end and from neighboring parts. The dense, conical, brittle ends of the bones are freshened by sharp, thin osteotome or chisel. The medullary canal, often closed by bone or fibrous tissue, is opened. No completely detached fragments of bone are left in the wound. The two fracture ends are crowded together tightly and are held together and fixed by appropriate splints and bandages. The wound is closed after all bleeding has been checked. Contractures of fascia and muscle are treated, overcome if possible.

The *benefits of this preliminary operation* are that it tends to prevent strain in the bone-graft by scar tissue and by contracted and contracting muscles; and that it prevents the flare-up of sepsis. The bacteria of latent infection commonly lurk in scar tissue about the ends of the bones; the removal of this cicatricial tissue gets rid of the infecting organisms. The removal of scar tissue is associated with considerable bleeding, difficult to control absolutely. If this inevitable hemorrhage is carefully controlled at the first-stage operation, at the second operation there will be a minimum of bleeding.

If a flare-up of the infection occurs after the first operation, it will follow a mild course. Its complete subsidence is almost a certainty. As a post-operative infection is generally fatal to the vitality of part or all of the graft, it is most desirable to avoid such an infection. There will be no fragments to be discharged, hence the duration of the infection will not be prolonged.

The discomfort of a second operation is well worth while if the likelihood of a septic infection is minimized by the preparatory treatment and the first operation. These remarks obtain, of course, in connection with old compound fractures with non-union. The World War compound fractures afforded a large experience which has been most valuable in this connection.

The **second stage** may be done after an interval of three weeks if no flare-up occurs. It is almost impossible to determine this exact time absolutely accurately. In a series treated by the two-stage (Forrester-Brown, Edinburgh) method, no infections developed. Most of the cases in this series were cases with a history of prolonged sepsis, or cases where a previous grafting operation had been spoiled by infection. (See the Operation of Bone-grafting: Technic.)

CHAPTER XXXIV

BONE-GRAFTING—METHODS—(*Concluded*)

SECTION C

End to end with fixation—"Step cut"—Comminution—Medullary graft—Sliding graft Osteoperiosteal graft—Massive inlay grafts: Albee's method, Mitchell's method, Henderson's method—Remarks on methods applicable to various bones—Remarks—Graft fractures.

1. **End to End with Fixation.**—The fragments having been freshened and those details carried out already mentioned as being necessary in a preliminary first stage (p. 978), the ends may be approximated and carefully engaged snugly together, irregularities being carefully fitted to each other. Immobilization of those replaced fragments by some form of non-absorbable metallic fixation material is indicated, dependent upon the bony fragments and what form of fixative material is best adapted to the conditions present in the individual case. It may be that a staple, a wire suture, a screw, a steel plate and screws, a band, or a steel plate and bands is the desirable material to employ. I have found that in an occasional case

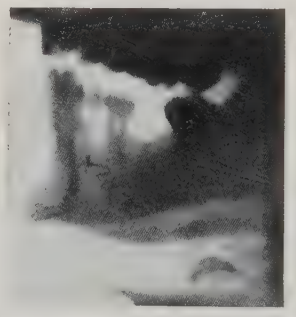


Fig. 1649.—Fracture of the body of the lower maxilla. Note small wire suture sufficient to hold fracture securely (Archibald Young).

an absorbable suture, chromic catgut or kangaroo-tendon, will be effective, but I have been so often disappointed by the inefficiency of absorbable material that I believe it is wise to use a non-absorbable one. Lack of fixation is so important a factor in the failure of a bone-grafting operation that the surgeon should take no chance of introducing this factor. The above will be the simplest procedure in a non-union case. Obviously, unless there is firm bony contact union will not result. A non-absorbable plate applied as just suggested is legitimately employed if it holds the fragments in firm contact. It must be remembered that the tendency, as plates are ordinarily applied, is for the plate to hold the bone fragments apart and separated; that if there is considerable leverage at the fracture site the screws

may become loosened and cease to hold the fracture; that the screws of a straight plate do not hold mechanically perfectly unless there is satisfactory

Fig. 1650.

Fig. 1651.

Fig. 1652.

Fig. 1653.

Fig. 1650.—Fracture with gross displacement and mal-union of digital phalanx; an adult male. Finger practically useless.

Fig. 1651.—Same as Fig. 1650; different view.

Fig. 1652. Same as Figs. 1650 and 1651, after open operation and fixation by fine "sprig" passed along phalanx. Full recovery of function.

Fig. 1653.—Same as Figs. 1650 to 1652; another view; after fixation.

(Archibald Young.)

contact of fragments; that the screws holding a steel plate may become a little loosened after ten days as healing proceeds. All these facts obtain and are most important in ununited fragments held by screw and plate.

Fig. 1654.—Fracture of shaft of femur in a young girl. Long oblique fracture (Archibald Young).

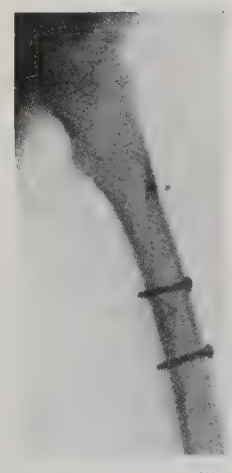


Fig. 1655.—Same case as in Fig. 1654. The fracture was perfectly reduced and held securely by two screws penetrating both cortices (Archibald Young).

Moreover, a plate does not in itself stimulate bone formation but does at its site retard osteogenesis. Plating, as Hey-Groves says, must always

be regarded as uncertain and unsatisfactory in non-union cases. *It must be used as only a means of immobilization. If it is so used, it must be applied especially carefully.*

Mere mechanical fixation of an ununited fracture will not bring about bony union ordinarily. Hey-Groves thinks that in certain suitably chosen cases one may sacrifice perfect internal mechanical fixation in order to simplify the whole operative procedure. External splinting to cause firm fixation is absolutely essential in these plated cases of non-union. A foreign body, a Sherman plate, for example, supplies nothing more than temporary fixation (Neuhof).

2. **The "Step-cut" Operation.**—Freshening the ends of the bone ununited so that the freshened surfaces fit together in an angular manner is especially useful in fractures of the upper arm and forearm. It may be used in the

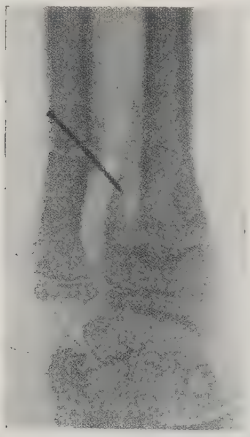


Fig. 1656.—Fracture of both bones of forearm, with impaction of radial fragments, and radial displacement of distal ulnar fragment, after fixation by open operation. Radial fragments corrected under anesthetic, but not directly fixed. Ulnar fragments fixed by single fine "sprig" (Archibald Young).

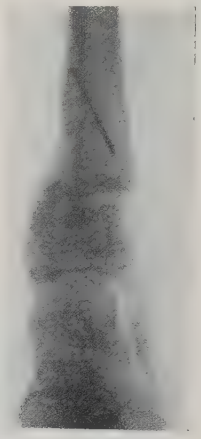


Fig. 1657.—Same case as Fig. 1656. Lateral view. Note wire "sprig" or nail (Archibald Young).

presence of a slight infection. This is applicable to those ununited fractures in which the original damage to the bone fragments plus the necessary removal of bone for refreshing purposes and plastic result in but little shortening of the shaft.

This plastic method is adapted to the shaft of the humerus, if the total loss of substance amounts to 2 or $2\frac{1}{2}$ inches or less. If the loss is greater than this, it is not applicable. Under this latter condition a bone-graft is indicated (see Fig. 1658).

Technic.—The bone ends must be freely exposed and properly freshened. Each end is cut off square. Half the thickness of each fragment is cut out from opposite sides in the shape of a step about $\frac{3}{4}$ inch long. This refreshed surface in each bone end is shaped with a square file so as to fit the other accurately. The two fragments are then fitted together (see Figs. 1659, 1660).

These surfaces are brought into apposition and held securely fixed by a temporary bone clamp. Two holes are then drilled through both flanges of bone in slightly different directions (for strength). Into each hole are carefully inserted and fixed split pins (cotter-pins) or two small bolts and nuts (Hey-Groves) or screws. Thus wide areas of healthy bone are brought together and held firmly in contact. If the bone-ends in which a "step-cut" operation is done are unsound, soft, or porous, very careful accessory immobilization must be used to prevent slipping of the fragments.

This operation is less well adapted to the bones of the lower extremity, for the necessary shortening of the bone would definitely handicap locomotion. The "step-cut" operation is best done on healthy bones. If the bone tissue in which the "step-cut" operation is done is seen to be thinned or is very unhealthy looking, it is wise to preclude the possibility of the "step-cut" operation from being a failure from too great motility, by augmenting the fixation by means of a bone plate, or by being especially careful about the use of external fixation apparatus. Osteoperiosteal grafts or even a bone-graft, such as that employed by Mitchell, might very advantageously be added.

A slight infection present or stirred up by the "stepping" operation will not preclude the success of the operation.

Mild sepsis in the presence of a fracture may be a stimulant to callous formation. Septic fractures, as a rule, may be delayed in uniting, but rarely result in non-union.

In *fractures of both bones of the forearm*, with an ununited radius and a solid ulna, it is necessary to shorten the ulna in order to bring the refreshed radial fragments in contact. This procedure ordinarily will be the only means necessary to bring about union.

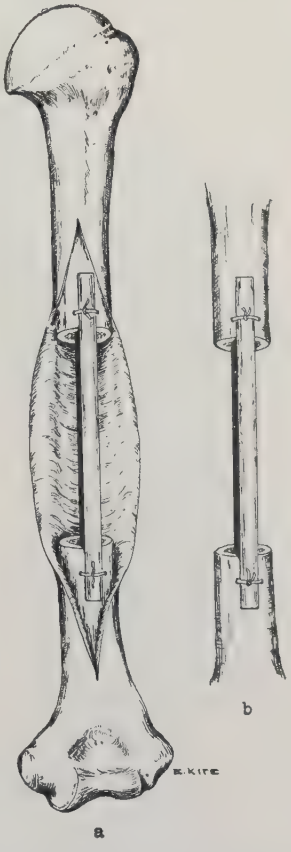


Fig. 1658.—Filling in a gap in the humerus with a transplant from the tibia, held in the grooved humerus by kangaroo-tendon sutures. In *a* the periosteal sheath has been preserved, to be sutured over and around the graft. In *b* the humeral periosteum has been lost, and only the graft and its periosteum connect the ends of the shaft. (From Bickham, Operative Surgery, vol. ii.)

3. **Comminution and Impaction of the Fractured Ends** (Waring and Milligan—see Fig. 1661). —The comminution is best done with an osteotome or a bone-cutting forceps, for 1 inch on each side of the fracture. The fragments are small, 1 by ½ inch. The fragments are loosened but not detached; the periosteum is preserved. It is important in impacting these comminuted ends to cause the fragments to dovetail and lock and be mortised together All hemorrhage is checked. The soft tissues are sutured carefully

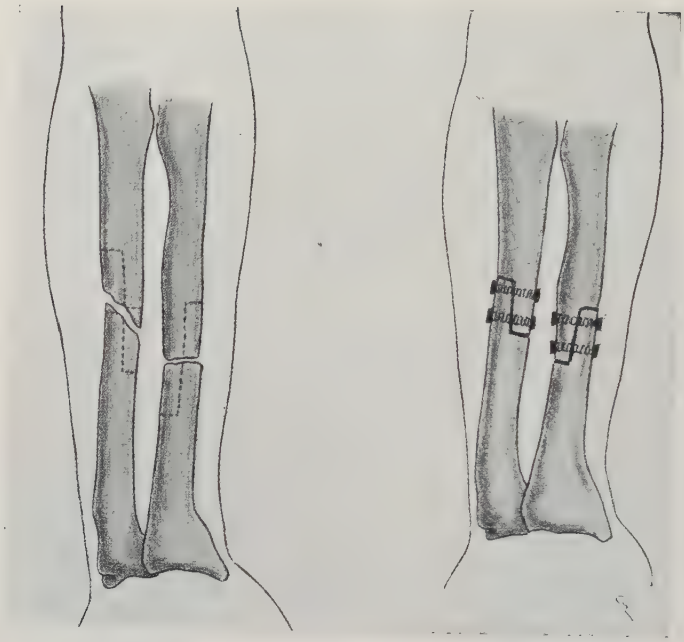


Fig. 1659.—Diagram of "step-cut" operation for the radius and ulna (after Hey-Groves, British Journal of Surgery, vol. 6, p. 211).

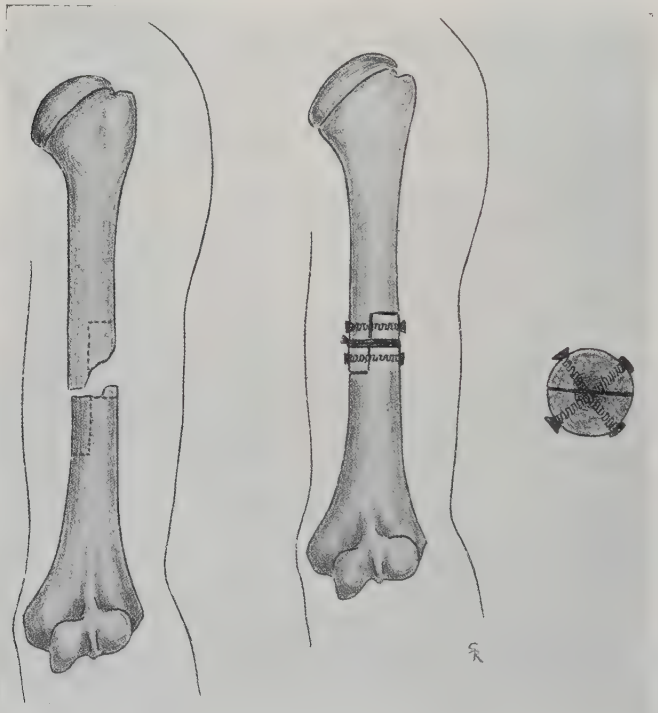


Fig. 1660.—A diagram of the "step-cut" operation for ununited fracture of the humerus (after Hey-Groves). Note the outline (dotted) of the step cut. Note the screws in position.

over this comminuted and artificially impacted bone. The fragments of bone are held surrounded by encasing soft parts. There is no drainage provided.

The limb is fixed by a splint which assists in maintaining the impaction of the bones. Plaster-of-Paris splinting is the most efficacious. Very careful supervision should be exercised in the after-care in order that this impaction be maintained. *x*-Ray should be used to record the position from time to time during the healing and the appearance and progress of the reparative process. After two or three weeks union will probably be well under way, but protection of the fracture must be maintained until union is solid.

The advantages stated by Waring and Milligan, who have consistently and extensively used this treatment, are as follows:

(*a*) A transverse or slightly oblique fracture becomes an impacted comminuted fracture, a fracture which nature always repairs. Fresh healthy raw bone surfaces are brought into apposition and the total raw areas in contact greatly increased, with the minimum amount of shortening.

(*b*) The reparative processes of bone are stimulated by the trauma of comminution.

(*c*) The amount of interference with the soft parts is a minimum, only an incision to expose the fracture being necessary.

(*d*) The operation is simple compared with the more elaborate bone-grafting method.

(*e*) No healthy bone or periosteum is removed in the comminution operation.

(*f*) No foreign bodies are introduced.

Fig. 1661.—Gunshot wound of the middle of the humerus. Many sequestra removed. Many plating operations done. Bones seen to be held apart by plate, an adequate cause of delayed and non-union. Plate removed, scarred bone excised, the freshened ends comminuted and impacted—firm union resulted (Waring and Milligan, British Journal of Surgery, vol. 9, 1921–22).

4. **Intramedullary Graft.**—An intramedullary graft is intended to fix the two fragments of a fracture in contact and in alignment by a bone-peg driven into each medullary cavity. The ends of the bone are freshened. The marrow cavities are slightly enlarged by a reamer or burr to form a firm bed for the graft. If the graft is taken from the tibial crest, it should be $\frac{1}{2}$ to $\frac{3}{4}$ inch in diameter and long enough to extend some $1\frac{1}{2}$ to 2 inches into the bone shaft. The medullary graft is best left irregular. Beef bone-pegs may be used.

The ends of the bones to be grafted are exposed. The limb is bent so that the lower fragment is easily accessible. The peg is driven into this distal medullary canal lightly. The limb is then manipulated by traction, counter-traction, and bending, so that the other end of the graft may be introduced into the medullary cavity of the proximal fragment (see Fig. 1699). This peg graft may be held more firmly in place if a drill hole is placed through the

shaft and graft and a suture of absorbable gut is passed and tied. If it is difficult to get the two fragments far enough apart to easily engage the medullary graft in the proximal fragment, the graft may be placed in the medulla of one fragment and set into the side of the end of the proximal fragment.

The intramedullary graft is applicable to humerus and femur, but a lateral graft may be advisable in addition in these heavier bones. Particularly is this true in the femur which is used for weight bearing.

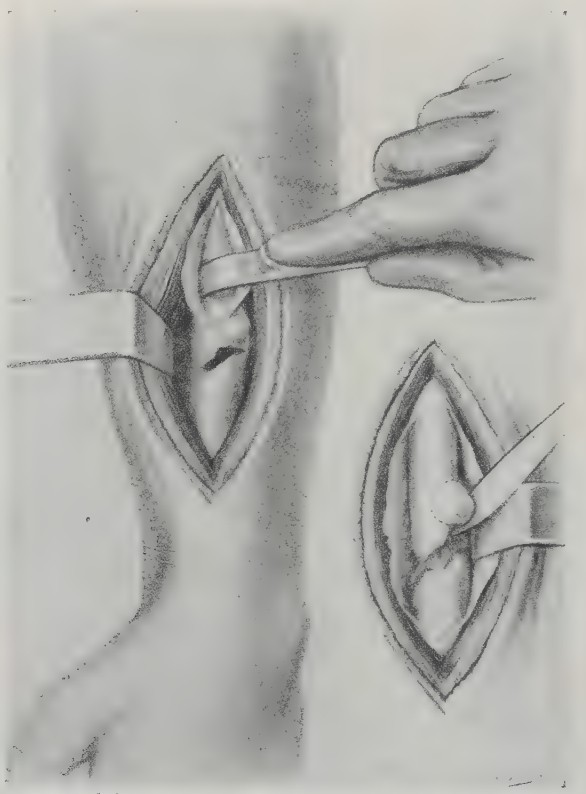


Fig. 1662.—The exposure of the radial shaft subperiosteally at the seat of an ununited fracture. Insert shows almost the completion of the subperiosteal exposure of the radius contiguous to the fracture line. (Chirurgie Reparatrice, etc. Tome II, Rottenstein.)

The medulla of the forearm bones has a small bore and the part placed within the bone is liable to fracture.

The bone suitable for osteogenesis is by this operation at a minimum in surface exposed. The medulla itself is plugged tight where it is in contact with the graft peg.

This method is successful and it also is at times unsuccessful. Failures of union occur due to motion at one or other end of the peg. In a few selected cases this method may be appropriately used. To secure ideal results absolute immobilization of the limbs will be essential as well as firm contact of each end of the peg graft with the host bone.

In this connection it is instructive and important to quote Davison and Christopher in their experimental work on the medullary beef bone-graft in dogs.

In a study of the fate of the boiled beef bone-peg in fractures in dogs, especially as used in the intramedullary graft, they concluded that the part of the boiled beef bone-peg which remains in aseptic stable contact with the

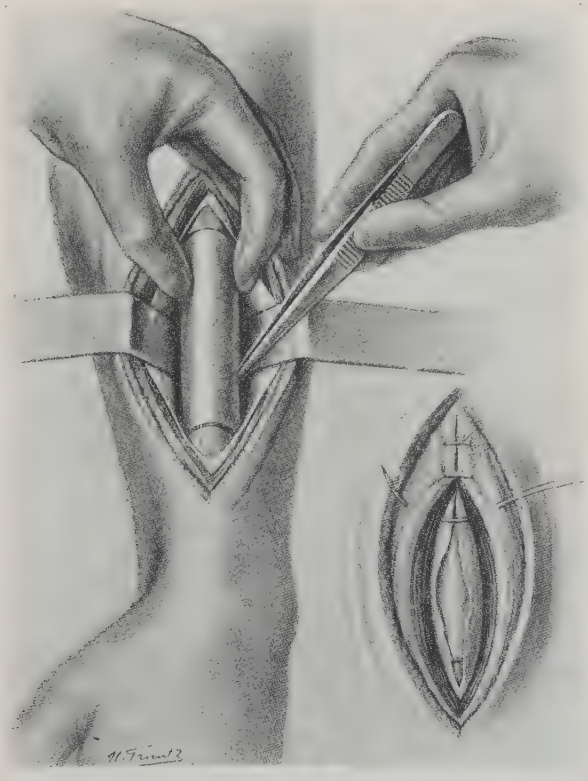


Fig. 1663.—Wrapping the osteoperiosteal graft about the refreshed fracture ends. The insert shows closure of the deep and superficial wound by interrupted sutures. No non-absorbable internal fixation sutures or plates were used (G. Rottenstein).

endosteum of the host, surrounded by living bone, becomes solidly embedded in new bone.

The peg undergoes gradual absorption and is replaced by new living bone, which later, in turn, is absorbed.

That part of the beef bone which lies between the fragments, but not protected by endosteum and not covered by living bone, even with aseptic surroundings, undergoes rapid absorption and disintegration and is not replaced by new living bone.

When one end of the beef bone-peg is not fixed in stable contact with the endosteum, but remains in position, there is absorption of both the peg and the surrounding live bone.

The internal callus, when the mechanical fixation holds and is aseptic, is limited by the beef-bone peg and does not bridge the line of fracture. The external callus is markedly lessened. The permanent or definitive callus is inhibited.

The series of experiments did not produce on dogs a single successful anatomical and functional result.

The causes of failure were: (*a*) Infection; (*b*) disengagement of the peg through failure of prolonged immobilization; (*c*) disintegration of the peg from absorption at the line of fracture of the bone.

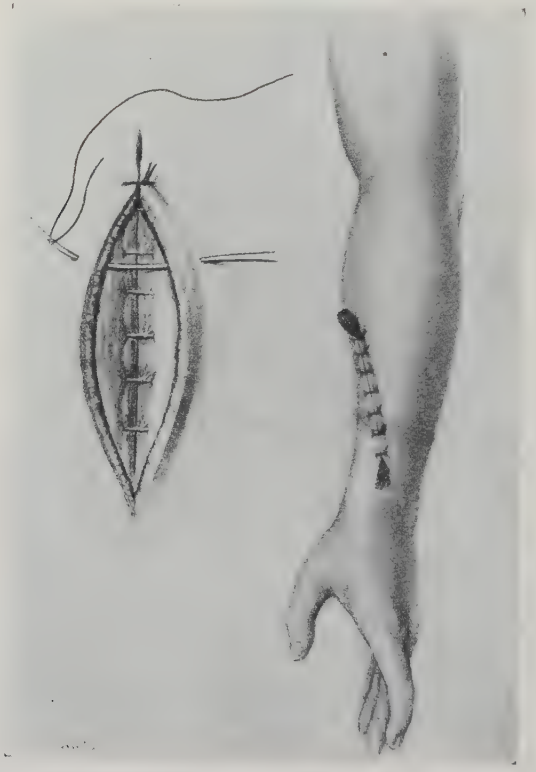


Fig. 1664.—The deep and muscular layers have been completely sutured. The deep wound is thus closed without leaving any pockets in it. On the right of drawing the superficial skin wound is shown closed by interrupted sutures. Tiny drains of silkworm-gut project from either end of the wound (G. Rottenstein).

In view of this and other experimental work, it is clearly seen how important it is to effectively and for a long period immobilize the limb in which the intramedullary graft is used.

5. **Sliding Grafts.**—The grafts are taken from the fragments themselves. Two parallel saw cuts are made in one fragment just double the length of the cuts in the other fragment. These two strips are freed at either end by right-angle narrow chisel cuts. The two strips of bone thus obtained are transposed. The long strip of bone is put into the gutter made by the re-

moval of the graft so that it lies across the line of fracture; the other strip fills the remaining gutter (see Fig. 1670).

These inlay grafts should be wedge-shaped so that they are $\frac{1}{4}$ inch wider on their periosteal surface as compared to their medullary surface. Wedge-shaping prevents the graft from slipping into the marrow easily.

These grafts may be held in place by their careful impaction, by bone-pegs above or through the grafts, and by absorbable suture. This sliding grafting method is simple and effective. The material of the graft cor-

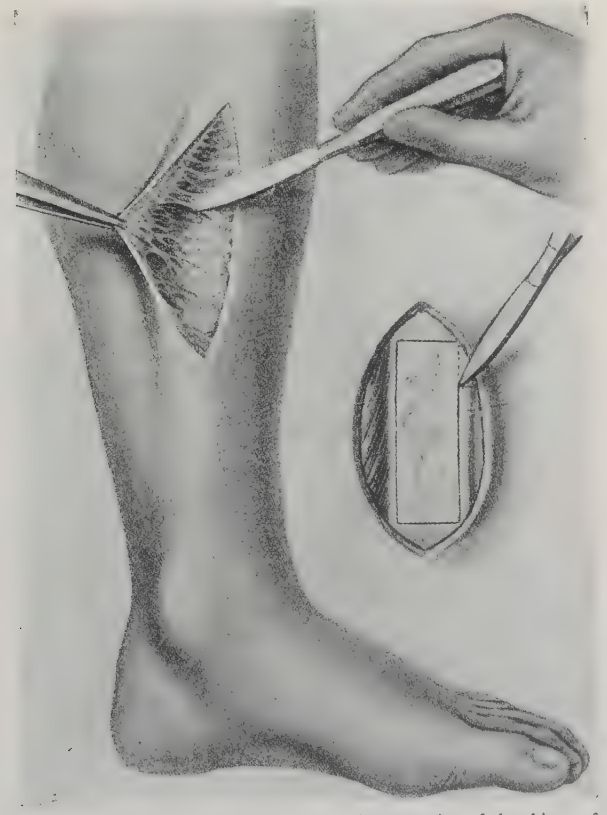


Fig. 1665.—Showing the incision over the tibia and the retraction of the skin on freeing it from the cellular tissue overlying the periosteum. The insert shows the marking and incision of the periosteal flap (G. Rottenstein.)

responds to the host bone in physical and chemical constitution. It is quickly applied.

It is not a strong graft, consequently the limb must be carefully protected and immobilized after its application. In non-union of the tibia it is employed most effectively.

It is also useful in non-union of the radius after the non-union gap in the radius has been obliterated by shortening the unfractured or healed ulna. It may be possible to hold this sliding graft by absorbable suture if the external splinting is carefully adjusted and maintained subsequently.

6. **Osteoperiosteal Methods.**—Osteoperiosteal grafts were originated and used by Ollier. The grafts are pliable and adaptable, easily applied. Codivilla transplants periosteal flaps with a thin shell of bone to bridge slight defects. The periosteal sheets or pieces may be 3 or 4 mm. thick and are sutured to each fragment or may be placed about the bone like a sleeve.

Lemaitre and Henri DeLagénière use an osteoperiosteal graft taken from the tibia. They have popularized this procedure. It is a layer of bone thin as cardboard with periosteum attached, removed by chisel and hammer

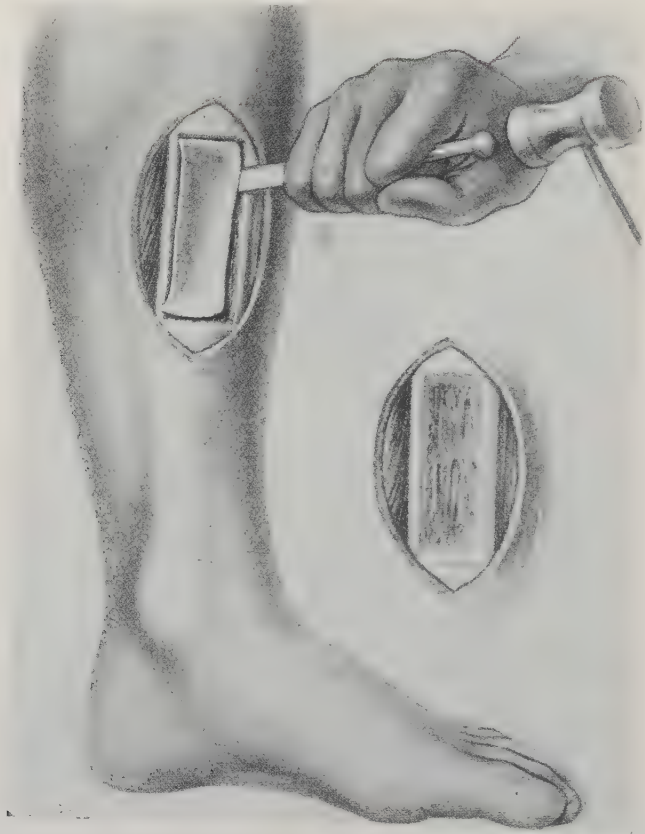


Fig. 1666.—Shows method of securing with chisel and hammer the osteoperiosteal graft from the surface of the tibia. The insert shows the appearance of the bed left after the graft has been removed (G. Rottenstein.

(see Fig. 1666). By using several thin sheets of bone the area to be grafted is covered by overlapping grafts held in place by sutures.

Chutro, Dujarier, and Fröhlich have used this method with success, 90 per cent. cured, laying the subperiosteal flexible grafts in freshened channels prepared in the host bone, subperiosteally, and sutured in place.

Technic.—These grafts may be removed from the tibia by a broad thin sharp osteotome chisel and hammer (see Figs. 1665, 1666). The tibia is exposed without injuring the periosteum. The graft is outlined by a scalpel.

The size of the graft is determined by the defect to be covered. The chisel is held almost vertically with the cutting edge firmly pressed against the bone. By varying the inclination sheets of bone with periosteum may be detached. The graft will be about the thickness of a United States dime. When the graft is removed it is placed in gauze compresses and then is transplanted, with as little delay as possible, to the host wound. By using several thin sheets and overlapping them the defect is closed.

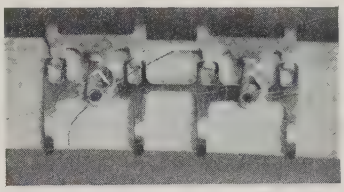


Fig. 1667.—The Smith bone clamp. The cam on the clamps with its radius has a capacity of creating a considerable fulcrum, and therefore it is discretionary with the operator to apply as much tension on the bone as he sees fit, and no more. The clamp will remain with the same tension until removed. In case the prongs of the clamp do not fit one end of the bone, these prongs can be easily bent with a pair of pliers to make a shorter curve that will fit. There is no danger of breaking the clamp. (The Smith Bone Clamp Co., Watertown, N. Y.)

If a bone is being grafted in which there is a slight loss of substance, it will be necessary to hold the separated ends of the fracture steady and relatively stable by means of silver or aluminum bronze wire carefully placed. Later the wire thus used may be removed. The wire envelops the periosteal grafts.

The Smith bone splint, which grasps the bone, is useful in this connection, encircling grafts and bone (see Figs. 1667, 1668).

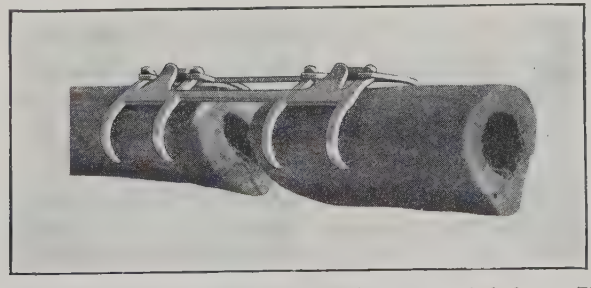


Fig. 1668.—The Smith bone clamp. Only the prongs of the clamp touch the bone. The clamp consists of two parts curved to fit the bone shaft and engage each other at any angle. In applying the clamp to the bone, insert each half on opposite sides of the bone and engage at the top; insert the key furnished with the clamp into the slot in each cam and turn to the right. This will clamp the bones and hold them at any tension desired. To remove the clamp, turning the cam back will relieve the tension and the clamp is easily removed. (The Smith Bone Clamp Co., Watertown, N. Y.)

7. **The Massive Graft and Inlay Grafting.**—If some standard surgical procedure offers a fairly favorable outlook for a satisfactory result, it should always be chosen in preference to one involving the transplantation of tissue.

The size of the transplant plays a part in its fate. The viability period of a transplant will be lengthened directly in proportion to the small size of the graft. The smaller the transplant, the better the outlook for viability.

If a solid bone-graft of some size is not required in a given space and position, multiple small bone-grafts (osteoperiosteal) should be used.

The delicate state of bone tissue detached for transplantation should be constantly in the surgeon's mind. The graft is highly susceptible to unfavorable influences: rough handling, drying, cooling, chemical contact.

Principles underlying the technic of bone-grafting.

Autografting denotes the complete detachment of one of the tissues of the body and its implantation into the same individual.

The greatest chances for success as far as viability is concerned attend the *auto*-transplantation of bone. By viability is meant that bone tissue should present physical and chemical characteristics which are associated with living bone tissue. *x*-Ray appearances and vital tissue staining are tests of viability in point. In the section on bone repair and the behavior of grafted bone will be found the facts of the present knowledge on these important matters carefully stated (see p. 913).

The clinical result and the experimental scientific result must each be clearly understood. The clinical value of a bone-grafting operation need not depend upon or correspond necessarily with the experimental evidence of the ultimate fate of the transplant. We are concerned directly and practically with the clinical result of the transplantation of bone.

Not knowing the fundamental happenings at the site of the graft and in the graft, the term "physicochemical stimulus" may be used to indicate the action a graft may have upon the host, the result being the replacement of the transplant by tissues closely resembling it.

A graft is disconnected from its blood and nerve supply. The necessity, therefore, for vascularization of the graft from the host is evident, and this is what first happens. The bone tissue, being elemental connective tissue and little dependent on nervous connections, suffers least from detachment and recovers best of many tissues after transplantation. In the absence of nervous and immediate vascular connection the physicochemical stimulus to the reparative processes must be the real agency at work after an auto-bone-grafting operation (Neuhof).

It is generally recognized that the introduction of a living autogenous bone-graft is the most satisfactory operation for the treatment of ununited fractures, and especially if there has been a definite loss of bone substance.

Exact Technic of a Bone-grafting Operation.—An Esmarch bandage should not be used. The field for the reception of the graft should be sterile. If the field is associated with an open wound, repeated bacteriological examinations should be made to determine sterility. (See Infected Non-union Cases, p. 978.)

The place from which the graft is to be taken and that into which it is to be implanted should both be carefully prepared before operation. It is very important that not only the immediate field of operation be cleansed but that a wide contiguous area should be equally scrupulously prepared. That is, if the graft is to be obtained from the shaft and crest of the tibia, the leg from the malleoli to and including the knee-joint should be pre-

pared, both anteriorly and posteriorly in the whole circumference of the limb, including the ham or popliteal space. Draping the parts with sterile sheets and towels later will thus preclude any contamination of the wounds by inadvertently observed slipping or sliding of the sterile dry goods employed *even* though sterile towels are clipped to the entire edge of the operative skin wound. A two-day or three-day preparation is wise.

Preparation, Local.—Shaving the skin, washing with soap and warm water and gauze wash-cloth twice daily. At the washing just previous to the operating room final preparation, cleansing with alcohol 70 per cent. should be done with care. A dry sterile gauze dressing should be applied, to await the operating room final sterilization, best after the patient is anesthetized.

The Final Preparation of the Fields of Operation, in the Operating Room.—This consists in careful bathing the parts involved in the preparation with sterile gauze and, first, alcohol 70 per cent. and, then, ether,. Finally, the skin is systematically covered with a tincture of iodin solution, 7 per cent., that is, full strength, in the immediate neighborhood of the incision and $3\frac{1}{2}$ per cent. strength iodin solution throughout the remainder of the prepared field.

A careful aseptic technic throughout the various steps of the operation is absolutely imperative.

The preparation of the surgeon's hands (see p. 750).

The sterilization of dry goods: sheets, towels, gauze, sponges, gowns.

The sterilization of instruments.

The sterilization of sutures.

The sterilization of rubber gloves.

These sterilization preparations are common to the operative technic of all fracture surgery, hence reference is made to this description for the sake of brevity and to avoid duplication.

There are certain technical operative details which seem to me of sufficient importance in the bone-grafting operation to require especial mention here, even at the risk of repetition.

The Surgeon's Hands.—If the surgeon's hands are ordinarily intact, careful manicuring and washing with ordinary castile or ivory soap and a nail-brush in running warm water should after ten minutes' active washing result in clean hands. Twisting the fingers and thumb about in a gauze compress or hand towel previously wet and soaped will insure cleaner fingers than by the ordinary methods. Hang-nails, cracks in fingers, and the base of the nails, should be touched after soap and water washing with tincture of iodin, 7 per cent. (full strength, U. S. P.). The hands after drying with a sterile towel should be soaked in alcohol, 70 per cent., and actively rubbed in the alcohol. The hands are then thoroughly dried on a sterile towel. This cleansing process extends to the elbow. Not only should the fingers be especially looked after but the wrists as well.

The *rubber gloves*, which after sterilization by boiling have been dried and sterile powdered, are put on before the gown is put on, the reason being that if the gown is put on first, the uncovered hands touch the

gown in various places. This contact is avoided by proceeding in this order. The gown's wrists are of knitted stockinet material, which is somewhat elastic and fits the wrist without constriction (no strings or lost buttons are troublesome here). The gloves are pulled up over the wrists of the gown.

I have gone thus into detail because I believe that the tactile sense of the surgeon should be employed in the conduct of *certain* fracture operations, and not be sacrificed to a standardized universal method. Information obtained through the tactile sense can never be replaced under certain conditions by information obtained through steel instruments, no matter how skilled the operator may be. The exercise of the direct tactile sense must be as carefully safeguarded as is the introduction of any necessary instrument into the wound (see p. 755).

I believe that the sterilized ordinary one-button cotton glove should be used over the rubber glove in any open operation upon a fractured bone, because contact of the rubber-gloved finger ever so lightly with a sharp bony spicule of bone may cut the glove. The skin of the finger is then in contact with wound fluids and tissues. One is thus a bit nearer to a possible source of infection, no matter how carefully the hand preparation may have been made. Whereas, if the rubber-gloved finger is covered by a sterile cotton finger, there is practically no such danger. Moreover, a cotton glove and a rubber glove may be as perfectly sterilized as a steel instrument. The likelihood of contaminating the wound by delicate occasional palpation under these conditions I believe to be eliminated.

The introduction, however, of sterile instruments unguided by the intelligent and skilled tactile sense into the depths of a wound is attended by more trauma and greater liability to damage than when intelligently guided after palpation. Much is gained by proper palpation. Much is lost by blind instrumentation. I am contending for direct contact with the parts concerned as opposed to the indirect method of approach. A direct method is correct, with a minimum of trauma. An indirect method is at best only inferential and may add insult to injury, and is undesirable.

Having all parts and instruments and surgeon's hands sterile, the following technical details will be necessary to a successful grafting operation. The most scrupulous asepsis must be maintained throughout the operation.

Preparation of the Bed for the Graft.—1. The *approach* to the fracture to be grafted through the skin incision should be ample. Less trauma will result if all parts are readily accessible. Moreover, assuming a sterile wound and primary union, a long incision will heal exactly as quickly and easily as a short and unsatisfactory incision.

2. The *bed of the graft* must be free from all scar tissue in soft parts and bone. All cicatricial tissue must be removed until healthy vascular bone is exposed. There must be provided an extensive bony bed for the graft. The bed must be cut on the surfaces of those fragments that will certainly be in continuity when the limb is in the desired position. The maximum cancellous bone consistent with the stability of the part must be exposed for

the bed. Active bleeding must be completely controlled and all oozing of blood and serum must be checked before the graft is implanted. The interposition of blood-clot interferes with the fusion of the tissues of the host and transplant. Early union is essential. Therefore keep a dry bed for the graft. A hematoma is a fertile source of infection, therefore, avoid a hematoma at the site of a bone-graft.

3. The *graft should be taken* ordinarily from the internal surface of the shaft of the tibia of the well side. Great length and strength are here possible in the graft. The graft should possess periosteum, cortex bone, and medulla; *i. e.*, all layers or parts of the bone. The graft may be secured from the tibia by two methods: by the saw or chisel (see Figs. 1467, 1666).

We are not dealing with inert wood, but with living bone. The most accurate carpentry may not afford an adequate blood-supply. Excellent *x*-ray appearances after the grafting operation may be found to give place to early absorption and fracture of the graft. On the other hand, a rough-fitting but carefully contacted graft rich in vascular possibilities will unite rapidly and firmly and adapt itself to stress and strain in its development.

The graft is obtained from the crest and inner side of the tibia through an incision of the skin down to the periosteum. The graft is made a trifle larger than the prepared bed. It is forcibly, firmly, and evenly tamped home so that medulla, cortex, and periosteum contact with their corresponding parts. Rapid regeneration of bone soon fills the gap left in the tibia. A hematoma may develop; unless excessive no harm results. Only very rarely has a fracture of the tibia followed the removal of the graft from the shaft of the bone and then only accidentally.

4. *The Size of the Graft.*—If there is a gap to be bridged between fragments, the graft should be at least about three times the length of the gap.

5. *Methods of Fixation of the Graft.*—If sepsis and interposing fibrous tissue are eliminated, the remaining essential to successful work is the proper maintenance of firm contact, immobility, of the graft with the host bone bed. The graft may be held by absorbable sutures, by bone-pegs, by mechanical wedging and tamping, or impaction with the host bone, and by metal screws, plates, pins, or wires. When there is little tendency to displacement, the absorbable suture may properly be employed, as in the forearm and certain leg fractures, and in the metacarpus. If the absorbable suture is used, it should be combined with some carefully applied external splinting.

The bone-peg and inlay graft may, under certain conditions, be so accurately fitted that absolute immobilization thereby will be obtained.

If there is likely to be a strain put on the graft, then metallic fixation is indicated. Hey-Groves uses the ordinary cotter-pin, $\frac{1}{16}$, $\frac{3}{32}$, $\frac{1}{8}$ inch in thickness. This seems to be perfectly satisfactory. The hole required for the reception of these pins is small as compared with that necessary for other metallic materials. Consequently there is very slight liability of fracturing the graft in inserting the pins.

The fact that wire and plates and screws have been unwisely and improperly employed does not militate against their proper use. Clinical ex-

perience has demonstrated that non-absorbable retention material does not prevent union of bone through grafting. Hey-Groves finds that the split pin (cotter-pin) is the most satisfactory immobilizing material.

It should be emphasized here that firm metal fixation will simplify the after-treatment of grafted bone, for much shorter immobilization of the joints above and below the fracture will be necessary. Consequently, early guided active motion can be used. Massage carefully given will help at an earlier period. In other words, more rapid restoration of function is obtained than by keeping the limb in plaster of Paris for months and months (Hey-Groves).

6. *After-treatment of Graft Cases.*—Immobilization is necessary until firm osseous union has occurred between the graft and host bone. The forearm is protected for from three to four weeks. Then guarded active motion is allowed and after ten days, active motion in light work is encouraged. This active use is sure to increase the reparative process and result in earlier restoration of the limb than is absolute fixation for a long period of time.

The duration of the period of immobilization will vary somewhat with the local conditions and the bone involved. An average of from four to twelve weeks will usually be sufficient for immobilization. The best method of immobilization is by a plaster-of-Paris splint. The joint above and the joint below the graft should be immobilized. The plaster splint may be reinforced at places of special strain by aluminum or wooden splints.

Albee's Inlay Method as Described by Neuhof.—A generous incision exposes the fracture.

The skin and subcutaneous tissues are well retracted.

The wound is protected by well-placed towel clips the whole length of the wound.

The bone-ends are exposed and freshened by chisel, osteotome, knife, motor burr, or saw.

If there is overlapping of fragments, extension and counterextension may completely reduce them; if not, they should be shortened sufficiently to lie closely together. Slight shortening of the limb will result and is to be expected.

After reduction, the fragments are held in correct alignment by a suitable clamp (Lane, Lowman, Magnuson). The periosteum, where the graft is to be placed, is incised longitudinally. The periosteal flaps are turned back on each side the necessary length of the graft bed.

Two parallel saw cuts, $\frac{3}{8}$ to $\frac{1}{2}$ inch apart, are made in the long axis of the bone, carried completely through from cortex to medulla cavity (see Fig. 1669). A chisel or single saw or twin saw may be used for this bone cut. The length of these parallel saw cuts will vary in each case, but will extend approximately from $2\frac{1}{2}$ to 3 inches into each fragment. These bone cuts should always extend far enough from the line of fracture to reach the normal non-sclerosed bone of each fragment. The bone strips between the saw cuts are removed by joining the far ends with an osteotome. These chisel cuts are made V-shaped so that a tongue-and-groove joint with the ends of the graft will be obtained.

If absorbable sutures are to be used, holes are bored in the cortex on each side of the gutter and are directed inward, toward the marrow cavity. These

holes are placed advantageously for the best fixation of the graft (see Fig. 1671).

The exact length of the inlay graft is marked by calipers, after measuring the gutter bed, on the tibia from which the graft is to be taken. The bone bed is rendered absolutely dry and is packed with hot salt compresses while the graft bone is being removed. The leg from which the graft is to be taken has been rendered sterile. The tibia from which the graft is to be taken is exposed by an incision over its crest. The soft parts are retracted and adequately placed sterile towels secured, the size and shape of the graft is outlined on the periosteum with the calipers or bent probe as a guide. The bone is cut to the medulla. The ends of the graft are fashioned to fit the prepared gutter, and the graft is immediately transferred to its bed. Double strands of kangaroo-tendon passed through the

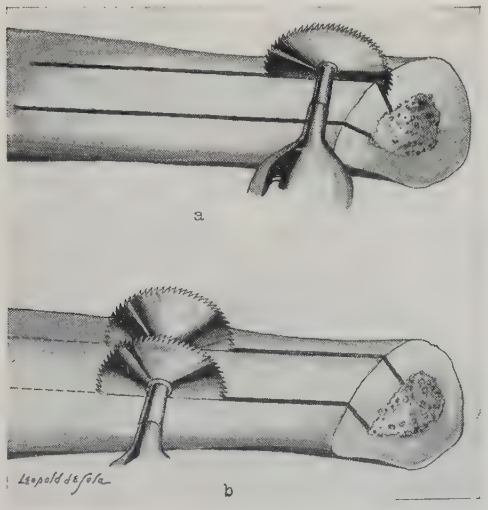


Fig. 1669.

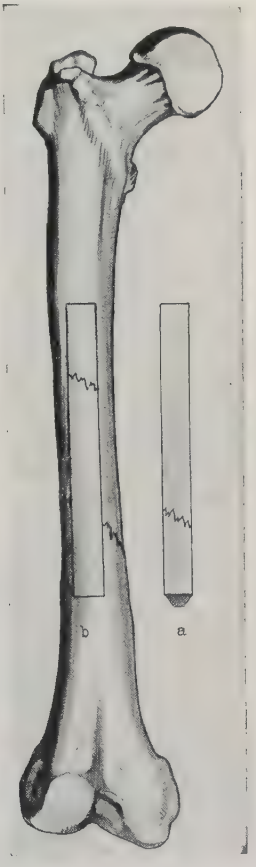


Fig. 1670.

Fig. 1669.—Cutting inlay bone-grafts: *a*, Graft with converging, or beveled sides, cut with a single saw; *b*, graft with parallel sides, cut with parallel saws. (From Bickham, Operative Surgery, vol. ii.)

Fig. 1670.—A fractured femur repaired by a reversed, beveled, inlay graft from the same bone. The graft, *a*, has been removed from the femur, the bone being carefully clamped and steadied during the saw-section through the region of the fracture, the graft itself containing its portion of the fracture, after which it is removed, reversed, and reinserted into the same bone-trough, but now, with its sound portion opposite the site of fracture, to brace it (*b*). (From Bickham, Operative Surgery, vol. ii.)

drill holes help to secure the graft. The graft is locked and quickly tamped in position. The site of fracture and graft is covered with the previously reflected periosteal flaps. The other soft tissues and skin are approximated without drainage.

The incision over the tibia from which the graft is taken is closed in a similar way and without drainage. The edge of adjoining muscle may be

placed in the cavity from which the graft was taken. A dry sterile dressing and appropriate plaster-of-Paris fixation splint completes the operation.

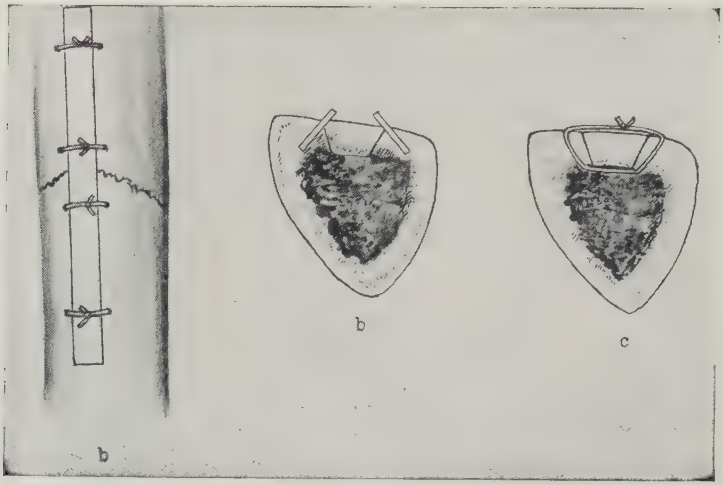


Fig. 1671.—Methods of retaining inlay grafts in position: *a*, Rectangular inlay, kept from falling out, or being depressed within the marrow-canal, by kangaroo-tendon sutures; *b*, beveled graft held in place by bone-pegs obliquely inserted through drilled holes (their outer ends being cut flush with the surface); *c*, beveled graft kept from inward displacement by its beveling, and from outward displacement, by the kangaroo-tendon. (Modified from Albee.) (From Bickham, Operative Surgery, vol. ii.)

A. Philip Mitchell's Method of Bone-grafting.—Mitchell uses the autogenous graft obtained from the subcutaneous inner surface of the tibia. This graft is applied as a massive lateral graft (see Figs. 1673–1677).

The bone to be grafted is approached through an adequate skin incision.

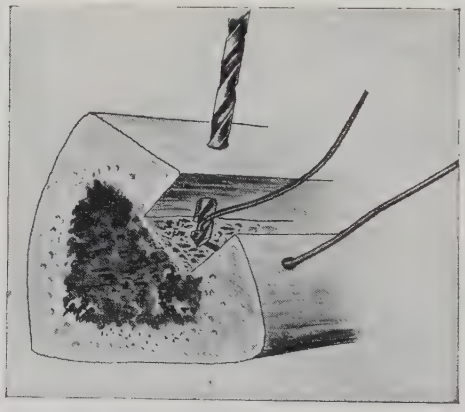


Fig. 1672.—Albee's technic, with special drill, of conducting kangaroo-tendon sutures into position, for tying in bone-transplants (from Bickham, Operative Surgery, vol. ii).

All scar tissue between fragments and extending into soft parts is excised in preparation for the graft. This step of preparation may of necessity have to be carried out at a preliminary operation because of sepsis. The ends of the host bone are prepared until healthy appearing vascular

bone is reached. The muscles along with the periosteum are then stripped from the bone for fully two inches from the fractured ends (see Fig. 1673) and for one-fourth the circumference of the bone. Beginning in a direction

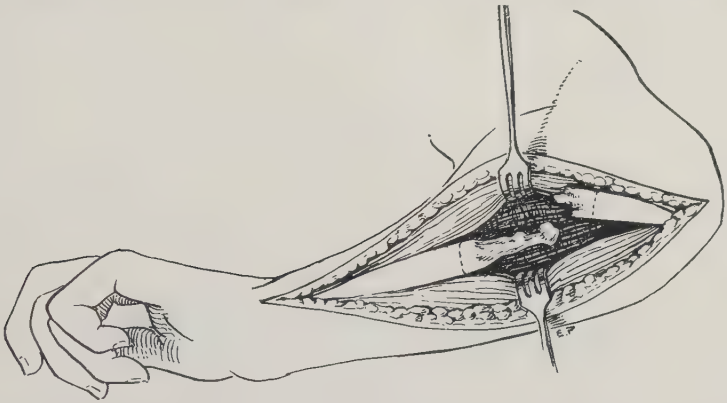


Fig. 1673.—Grafting operation in fracture of (ulna) a long bone. Exposure and preparation of the field for removal of sequestrum (after A. P. Mitchell, British Journal of Surgery, vol. x, p. 264).

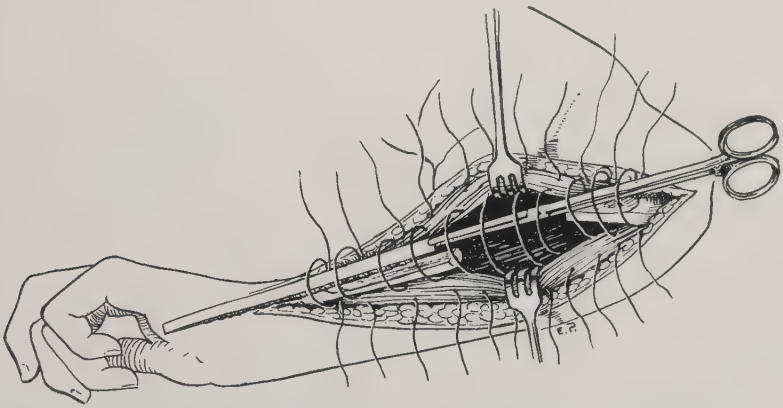


Fig. 1674.—Introducing the graft from the tibia to its prepared bed. Note sutures intended to secure graft in position. (after A. P. Mitchell, British Journal of Surgery, vol. x).

Fig. 1675.—Diagram illustrating the placing of the interrupted retentive sutures. Note graft lying in perfect contact with bone. Note suture passing through muscle and periosteum on either side (after A. P. Mitchell, British Journal of Surgery, vol. x).

away from the point of fracture and extending the whole length of the bone as exposed, a thin layer of bone is removed with a fine osteotome or chisel (see Fig. 1674). The bone is to be divided in places to open the medulla. The same procedure is repeated on the other fragment.

Care should be taken that the bed for the graft is cut on the surface of the fragments that will be in continuity when the limb is in the desired position. For the internal fixation of the graft an absorbable suture is used. These retaining sutures are passed through the reflected periosteum and muscles on either side of the prepared bed (see Fig. 1675). The sutures having

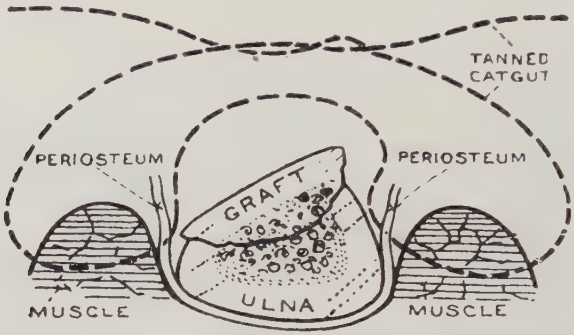


Fig. 1676.—Diagram in more detail to show the method of the introduction of looped catgut sutures for the fixation of the graft (after A. P. Mitchell, British Journal of Surgery, vol. x).

been placed, the muscular osseous bed is ready for the reception of the tibial graft (see Fig. 1674).

Broad, accurate, and fresh bony contact is thus assured. If the graft can be efficiently maintained in fixed contact, the success of the graft may almost be guaranteed. The wound is packed firmly with gauze to stop the oozing of blood, and the part is covered with a sterile towel.

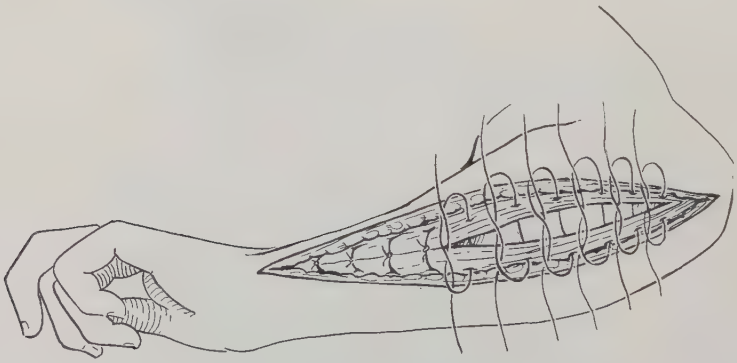


Fig. 1677.—Suturing partially completed. Remaining sutures to be drawn tightly over graft (after A. P. Mitchell, British Journal of Surgery, vol. x).

The tibial graft is taken of measured length. It is cut by a single circular saw, electrically driven. The graft should be transferred at once after it is secured. The graft should not be washed, or handled and laid aside.

The host wound should have been made ready for the reception of the graft immediately it is prepared. The graft is placed underneath the catgut suture (see Fig. 1674). A few additional catgut sutures may be needed to

approximate the deep structures (see Fig. 1677). The skin is closed with non-absorbable sutures.

The limb must be securely controlled in the correct or corrected position by a plaster-of-Paris splint. The ordinary care of a plaster-of-Paris encircling splint should be taken. If undue swelling follows the application of the splint, the plaster should be divided. Absolute immobilization of the part enclosed is to be maintained for six weeks.

After six weeks the splint is removed. An *x*-ray is taken occasionally to determine the progress of the reparative process. Protected use of the limb encourages the healing of the bone. The time involved in getting from partial to complete function of the limb will depend upon: 1. The presence or absence of other serious disabilities; nerve lesion; muscle injury. 2. The degree of union between host bone and graft. 3. The individual bone involved. Radiograms taken at six- to eight-week intervals will afford suitable record of progress in healing. This is true for the upper extremity. If the graft is for non-union of the tibia, the immobilization should be for a much longer period, perhaps six months. Some support should be afforded the tibia for from three to six months longer when the part is used and weight is borne on it.

Mitchell has studied 70 cases in which this method has been used. It was successful in 95.8 per cent., and a failure in 4.2 per cent. This was a series of cases of ununited fracture following war injuries.

The fact that the intramedullary and inlay methods use a small graft makes them unsuited to war injuries. On the other hand, this method of Mitchell is admirably adapted to civil injuries and will prove successful.

Henderson's method of choice in bone-grafting is the use of what he terms a massive graft. It is applied to the freshened host fragments as already described. He takes the graft from the tibia, as is usual. He holds the massive graft to the fragments by carefully placed beef bone-screws. He feels, with Mitchell, that the massive graft gives a high degree of internal fixation, broader contact, a long period of support. The time of absorption and replacement in the massive graft is longer than in a smaller graft, so that when the weakest moment of the grafting period is reached (six to eight weeks following the operation) the graft is less likely to fracture.

This method of Henderson is like the method of Mitchell plus the use of beef bone screws.

Henderson has made a distinctly practical contribution to the technic of bone-grafting surgery by the demonstration of the usefulness of the beef bone screw as an immobilizing agent (see p. 1002).

Henderson's method of using a massive graft held by absorbable catgut and beef bone fixation screws has given satisfactory union in:

(*a*) Fractures of the shaft of the femur, 62.5 per cent.
(*b*) Fractures of the tibia, 81.8 per cent.
(*c*) Fractures of the humerus, 70.2 per cent.
(*d*) Fractures of both bones of the forearm, 85.7 per cent.
(*e*) Fractures of the radius alone, 93.3 per cent.
(*f*) Fracture of the ulna alone, 85.7 per cent.

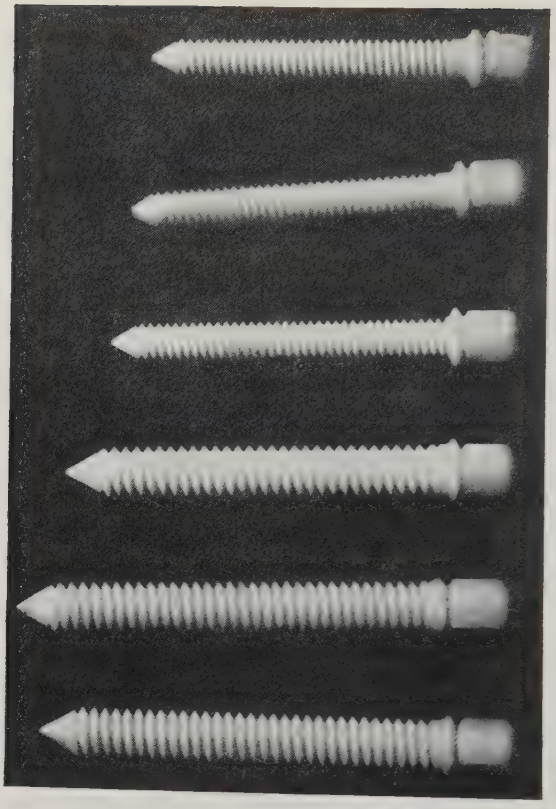


Fig. 1678.—Beef bone screws (after **Henderson**).

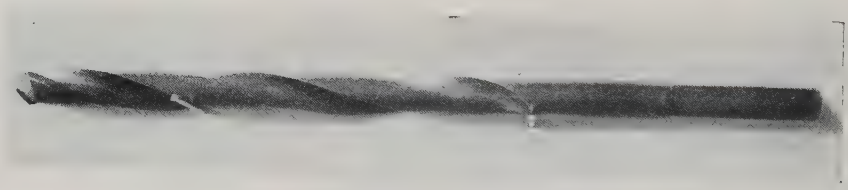


Fig. 1679.—Twist drill No. 17 (after Henderson).

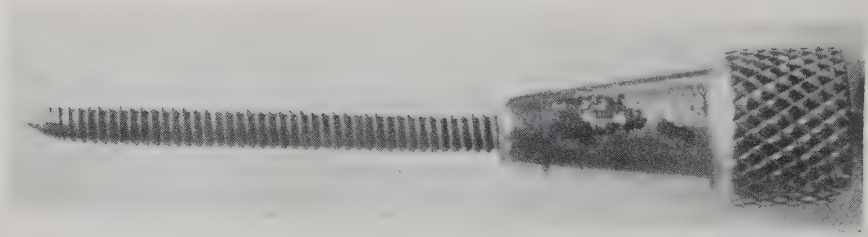


Fig. 1680.—A straight handled tap. Tap in handle (after Henderson).

Henderson studied 184 cases which were traced for a considerable time after operation; 75 per cent. of these obtained union, and 25 per cent. failed to obtain union.

Regional Grafting.

Humerus.—Ununited fractures of the humeral shaft are perhaps the most difficult to treat. Shortening of the humerus is relatively and absolutely

Fig. 1681.—Straight handled tap (compare with 1680 (after Henderson).

unimportant from a functional viewpoint. Consequently, the "step-cut" operation—and the steps cut should be long (Mitchell)—is especially adapted to the humerus.

Fig. 1682.—Enlarged end of the hexagonal wrench of Fig. 1683 necessary to receive the carefully made bone screw (after Henderson).

To fractures of the upper end of the humerus an intramedullary graft reinforced by osteoperiosteal grafts wrapped about the fractured bone site is applicable. Often an impaction of the freshened fragments will be successful.

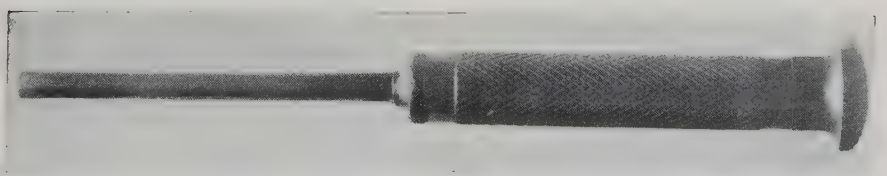


Fig. 1683.—Straight handled wrench with hexagonal tip to hold hexagonally headed bone screw. Compare with Fig. 1682 (after Henderson).

Ununited fractures of the lower third of the humerus are especially difficult to handle if combined with loss of motion at the elbow. Intramedullary pegs combined with osteoperiosteal grafts have proved successful. Internal metallic fixation may be needed to supplement these grafting operations in

the humerus, combined with very carefully applied plaster-of-Paris splints ordinarily immobilizing the shoulder, elbow, and wrist, combined with a

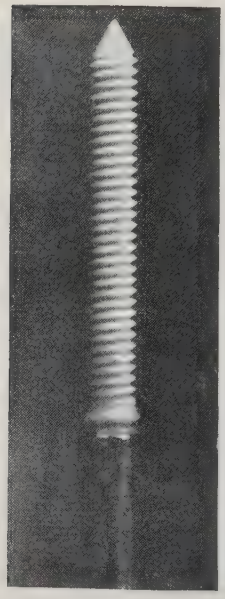


Fig. 1684.—A beef bone screw held in the instrument tip used for placing the screw (after Henderson).

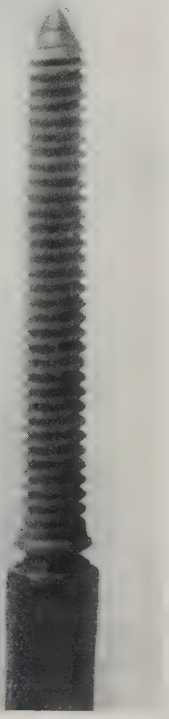


Fig. 1685.—Straight handle wrench holding the bone screw ready for insertion (after Henderson).

circular of the chest (a spica of the shoulder encircling the thorax) (see Fig. 1477).

Radius and Ulna.—Non-union of the radius means radial deviation of the hand, and a weak grasp because of shortening of the radius or displace-

Fig. 1686.—Offset handle wrench with a beef bone screw in socket (after Henderson).

ment of the distal fragment of the fractured bone. When the radial lower fragment is short (one inch or a little more in length), shortening of the ulna to correct the radial deviation will permit union of the radial fragments.

Fig. 1687—Beef bone screw. Fracture of tibia, internal malleolus. Two weeks after operation. Note beef bone *in situ* (Henderson).

Fig. 1688.—Beef bone screw. Fracture of tibia, internal malleolus. Three months after operation. Note fracture line firm. Beef bone *in situ*, but process of absorption beginning. Compare with 1687 (Henderson).

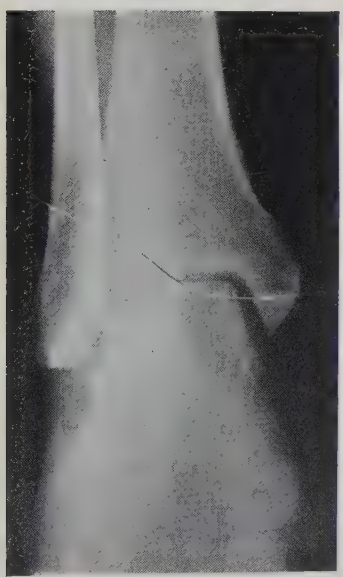


Fig. 1689.—Beef bone screw. Fracture of tibia, internal malleolus. One year after operation. Note that process of absorption of beef bone screw is progressing (Henderson).

Fig. 1690.—Beef bone screw. Fracture of tibia, internal malleolus. Six years after operation. Note absence of beef bone, completely absorbed. Compare with 1688 (Henderson).

Fig. 1691.—Beef bone screw was used in this fracture involving ankle-joint. Note line of fracture in tibia (Henderson).

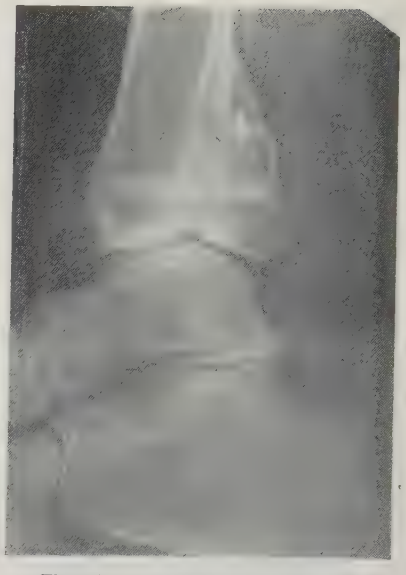


Fig. 1692.—Beef bone screw *in situ*, same case as Fig. 1691. Note fragment firmly held by screw and integrity of the screw apparent (Henderson).

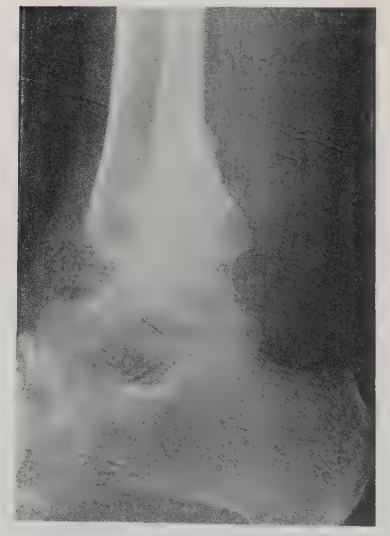


Fig. 1693.—Beef bone screw in fracture of the lower end of tibia entering joint. Note partial absorption of screw (Henderson).

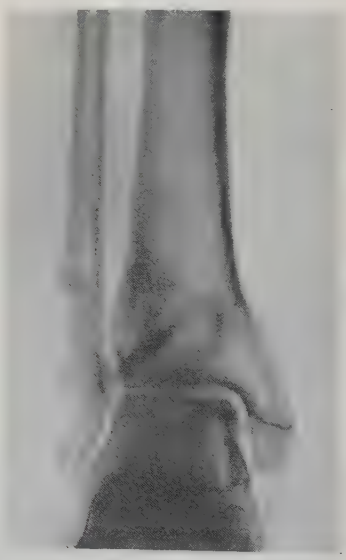


Fig. 1694.—Beef bone screw in fracture of lower end of tibia into joint. Note the disappearance of the screw by absorption and the restoration of the joint, with a smoothing off of the irregular joint surface seen in Fig. 1693, 9 months after operation (Henderson).

Previous to a graft operation on the radius the radial deviation of the hand is to be corrected and forearm supination secured. Thus all strain will be removed from the graft after it is placed.

Fig. 1695.—Use of peg-transplant in fracture of anatomical neck of humerus. (Modified from Davison and Smith.) (From Bickham, Operative Surgery, vol. ii.)

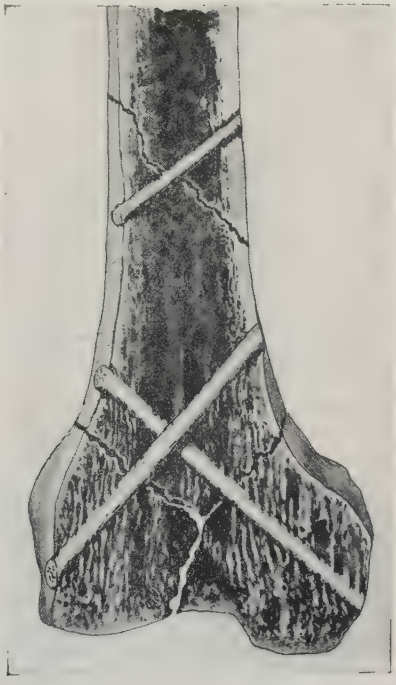


Fig. 1696.—Use of transplant bone-pegs in the treatment of fracture. A single peg is seen employed in the upper single, oblique fracture of the shaft of the femur, and two pegs in the lower fracture involving the femoral condyles (from Bickham, Operative Surgery, vol. ii).

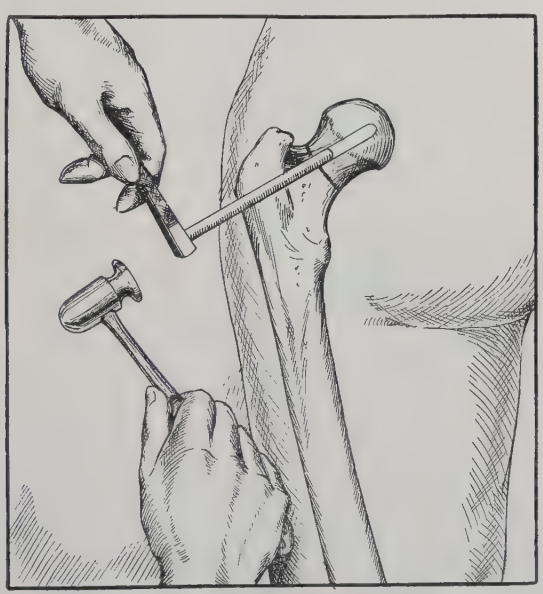


Fig. 1697.—Manner of driving home the bone-graft peg in intracapsular fracture of the femoral head (from Bickham, Operative Surgery, vol. ii).

In ununited fractures of both bones of the forearm, radius and ulna, slight shortening of each bone and fitting contact, and then grafting one or both bones, is indicated. There is no serious objection to grafting both bones at the same time. If ankylosis of either the superior or the inferior radio-ulnar joint is present, any motion in supination or pronation which is secured because of the non-union will be entirely lost when solid union is obtained.

The application of an inlay graft of ordinary size to one of the bones of the forearm involves often so much trauma and mutilation of the recipient bone that little is left, and the bone-forming possibilities are so greatly handicapped that the graft fails to live.

To yield the best results the medullary graft should project well beyond the sclerosed end of the host bone so as to penetrate and lie in contact with

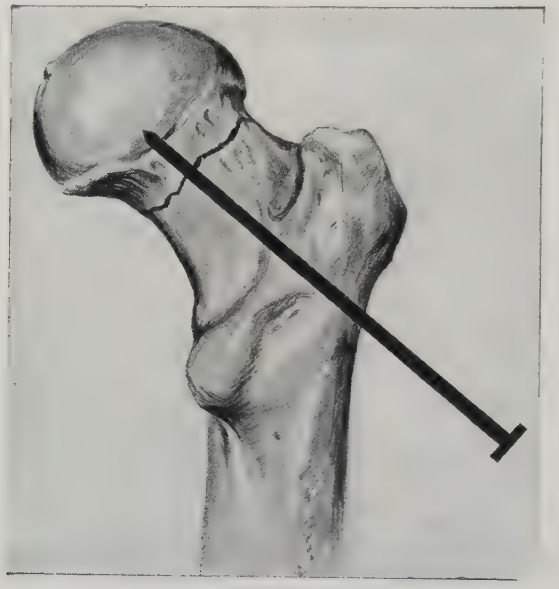


Fig. 1698.—Fastening the head of the femur with a nail in intracapsular fracture (from Bickham, Operative Surgery, vol. ii).

healthy bone-marrow. When the ends of the ununited bone are sclerosed and tapering, the tapering end may be split with a saw for some distance, and a tibial graft may be engaged between the cleft ends (Hess).

One always may use a massive graft after the method of Mitchell (see p. 998) in these difficult forearm fractures.

Tibia.—In ununited fracture of the tibia a sliding graft is especially applicable. The autogenous massive graft of Mitchell is also satisfactory here.

In a tibia ununited, needling the two ends of the fragments and wrapping the seat of the prepared fragments with periosteal grafts is effective.

Femur.—In a transverse uncomminuted fracture of the femur an intramedullary graft will be successful if the graft extends a considerable distance into the sound bone. Additional internal fixation and very careful external fixation will be needed in these cases.

A massive lateral graft (Henderson) may be successfully used in ununited fractures of the femur.

Where there is a considerable overriding of fragments in shaft fractures, instead of shortening the bone it will be wise to use traction and counter-traction in order to stretch the muscles and fascia and fibrous tissues of the limb. Then after some days (if necessary) of preliminary traction, the full length of the limb or nearly so having been secured, one may proceed with that form of operation for non-union which the necessities of the case demand.

The above is especially applicable to non-union of the fracture of the shaft of the femur. If the fracture with overriding

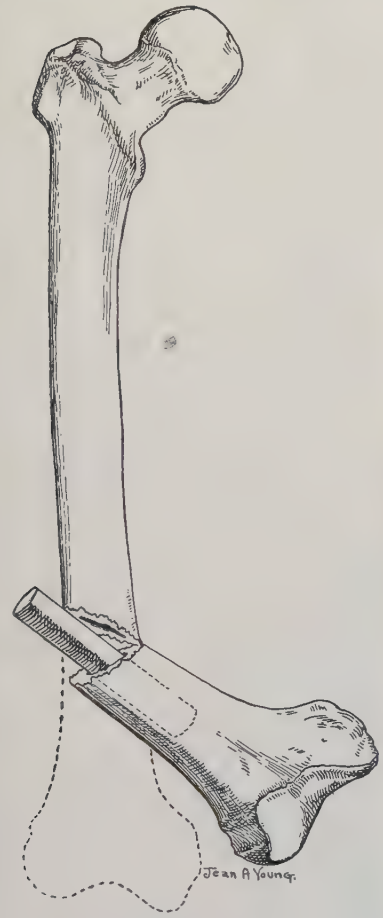


Fig. 1699.—Introduction of a medullary transplant into the canal of a fractured bone of a single-bone limb (from Bickham, Operative Surgery, vol. ii).

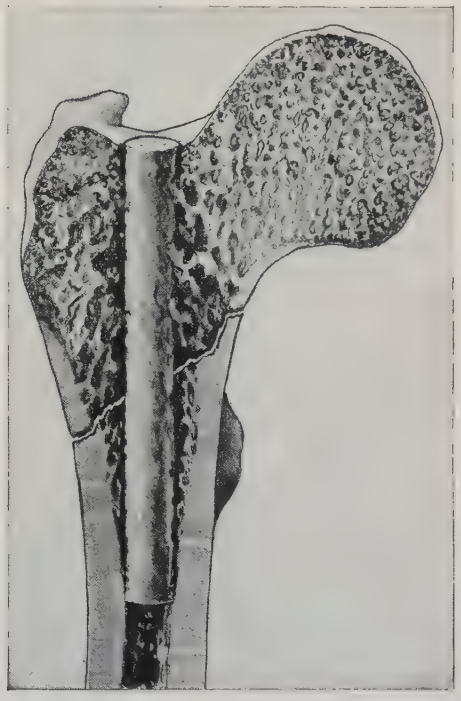


Fig. 1700.—Peg-transplant, or combined peg and medullary transplant, in an intertrochanteric fracture of the femur (from Bickham, Operative Surgery, vol. ii).

of the femoral shaft is of comparatively recent origin—two or three months' duration—it may be that distraction of the fragments may be obtained at the time of operation. This is most easily accomplished by traction according to Martin's method: a canvas strip over the proximal end of the distal fragment furnishing the means for a direct pull on the soft parts through the distal fragment.

Non-union of the Inferior Maxilla.—Non-union is rather frequent following fracture of the jaw. The functional disability associated with ununited fracture of the inferior maxilla is an unnecessary disability in most cases.

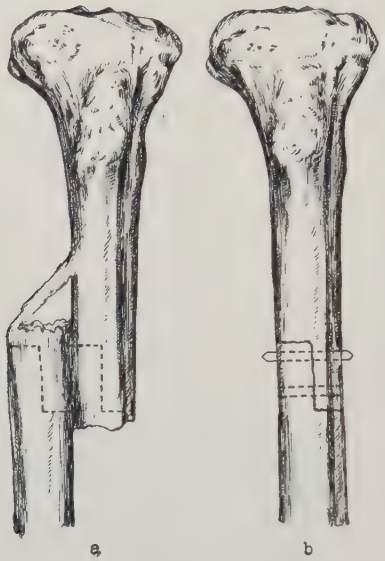


Fig. 1701.—Operation for osteosynthesis of bone ends by incision, reshaping and suturing, pegging (or otherwise coaptating) the reshapen ends (from Bickham, Operative Surgery, vol. ii).

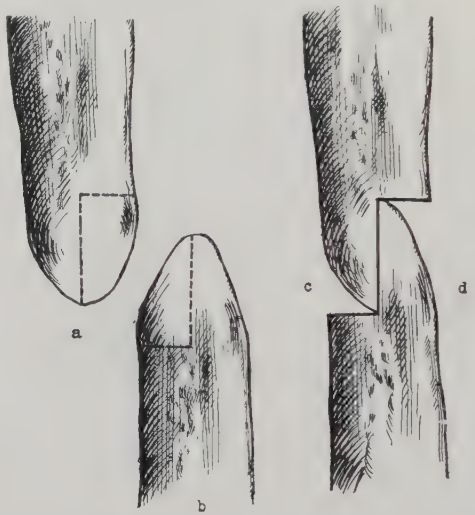


Fig. 1702.—Operation for ununited fracture in which the opposite ends of the bones (*a* and *b*), are cut into a reciprocally receptive angulated end and angulated cavity, which are then fitted into each other, as at *c* and *d*. (From Bickham, Operative Surgery, vol. ii.)

The desirability of bony union in this situation is obvious. Correct alignment and restoration of the normal maxillary arch and maintenance of accurate occlusion are the ideals behind all treatment.

Subjective symptoms of a functionally useful jaw for mastication are more important than objective signs of union.

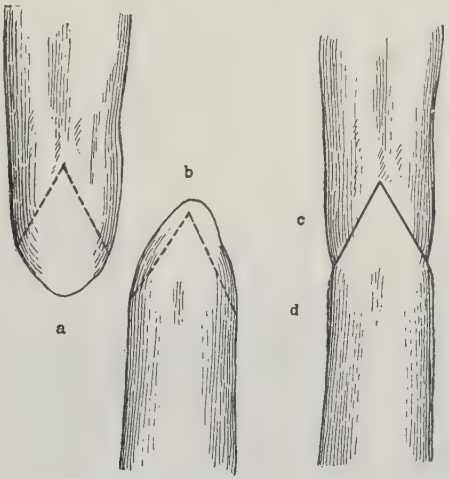


Fig. 1703.—Operation for ununited fracture in which the ends of the bones are reshaped in a reciprocally receptive wedge-shaped manner (*a* and *b*), so as to be mutually receptive of each other (*c* and *d*). (From Bickham, Operative Surgery, vol. ii.)

In the ascending ramus the nearer the fracture is to the condyle, the less is the disability.

In the horizontal ramus the nearer the fracture approaches the symphysis, the greater is the disability.

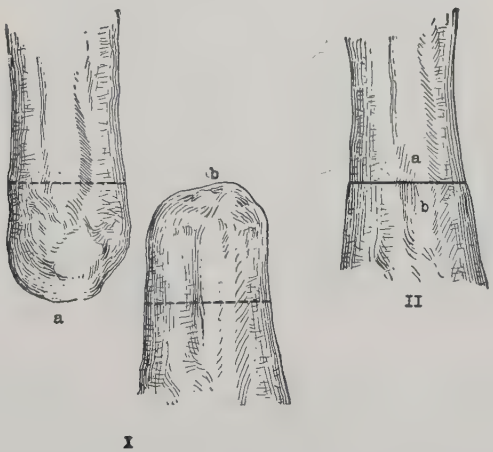


Fig. 1704.—Method of treating a false joint in a single bone limb by transverse excision of the ends and coaptation of the shafts: I, Lines of excision; II, coaptated ends. (From Bickham, Operative Surgery, vol. ii.)

The fundamental principle applicable to all cases of non-union obtains in cases of non-union of the jaw, namely, no grafting operation should be attempted until several weeks have passed without signs of infection. Oc-

clusion of the jaws must be maintained for purposes of fixation until firm union of the transplant to the adjacent bone ends or sides has taken place.

The treatment of ununited fractures of the lower jaw as described by Cole is somewhat as follows (see Fig. 1462):

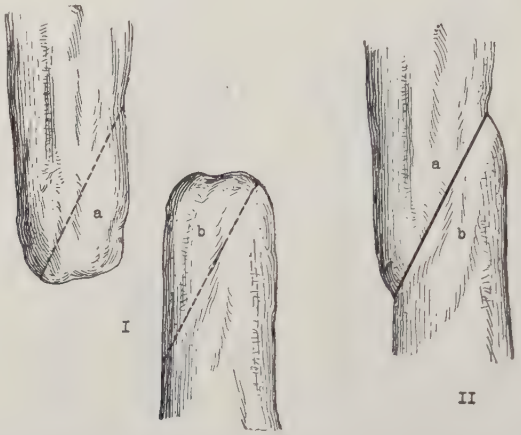


Fig. 1705.—Method of treating a false joint in a single bone limb by oblique excision of the ends and coaptation of the shafts: I, Lines of excision; II, coaptated ends. (From Bickham, Operative Surgery, vol. ii.)

Plating.—Plates may be used to hold fragments in close approximation provided at the same time union is not sacrificed to occlusion.

Wiring.—Cases with little or no loss of substance may be securely held by aluminum bronze wire. If it is possible to avoid opening the mouth in

Fig. 1706.—Ollier's method of treating ankylosis of two parallel bones complicated by fracture: I, The ends of the fractured bone, *c* and *b*, are obliquely beveled in the direction of the sound bone, from which latter a broad wedge of bone, *a*, is mobilized. II, The loosened wedge of bone, *a*, is then reversed and applied to the two freshened ends. (From Bickham, Operative Surgery, vol. ii.)

freeing the fragments, this is very desirable. The danger from opening the mouth is exaggerated.

Bone-grafting.—The following operation, described by Percival Cole, of London, England, is a satisfactory procedure[1]:

[1] British Journal of Surgery, vol. 6, p. 57.

A suitable dental splint is used to retain the fragments in the position of teeth alignment.

A preliminary operation is done through an external incision, to shut the mouth off from the outside bone ends. This wound is drained, and after about three months the reconstruction graft operation is done as follows: Two or three days previous to the grafting provision is made for interdental splinting to keep the fragments correctly and permanently aligned until the graft is healed. Intratracheal anesthesia is used. The anesthetist is away from the operative field.

A curved neck incision is used uncovering the area of fracture (see Fig. 1464). The ends of the fragments are exposed, freshened, and shaped for

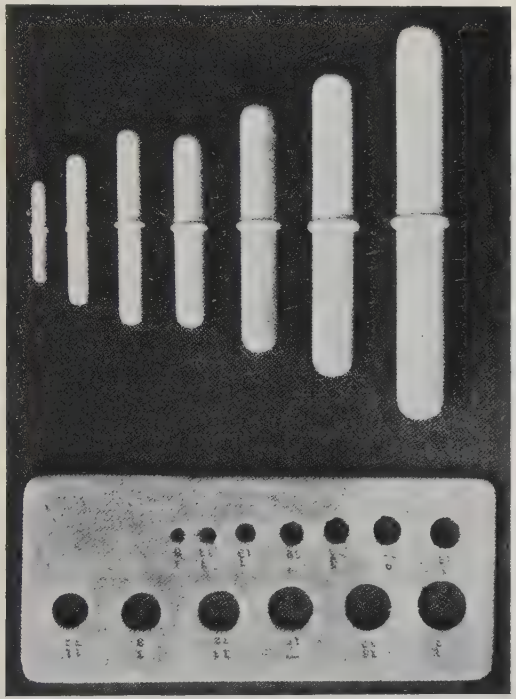


Fig. 1707.—Ivory or bone-pegs with metal gage (from E. W. Hey-Groves, Modern Methods of Treating Fractures, p. 165).

the graft (see Fig. 1465). The tibia is uncovered and the graft shaped from it. The plates that are to hold the graft in position are screwed to the graft (see Figs. 1466 and 1467). This prevents splitting of the graft by screws where it is free. The graft is detached and fixed in the gap it is to fill, fastened to the corresponding fragment of the jaw (see Fig. 1471), and the wound is closed (Figs. 1468–1472).

A similar technic is used when a portion of a rib is taken for the graft (see Fig. 1470).

The Pedicled Graft (*Cole*).—The utilization of the attachment of the cervical fascia, the platysma, and, at the symphysis, the anterior belly of the

digastric as an attachment for the graft, was suggested to Cole by the sound union occurring in comminuted fractures.

The same skin incision as already shown is used. The skin is reflected. The posterior fragment is thoroughly exposed. The tip of the anterior fragment is exposed. The anterior fragment is divided longitudinally and obliquely, keeping the soft part attachments on a pedicle (Fig. 1474). Fine

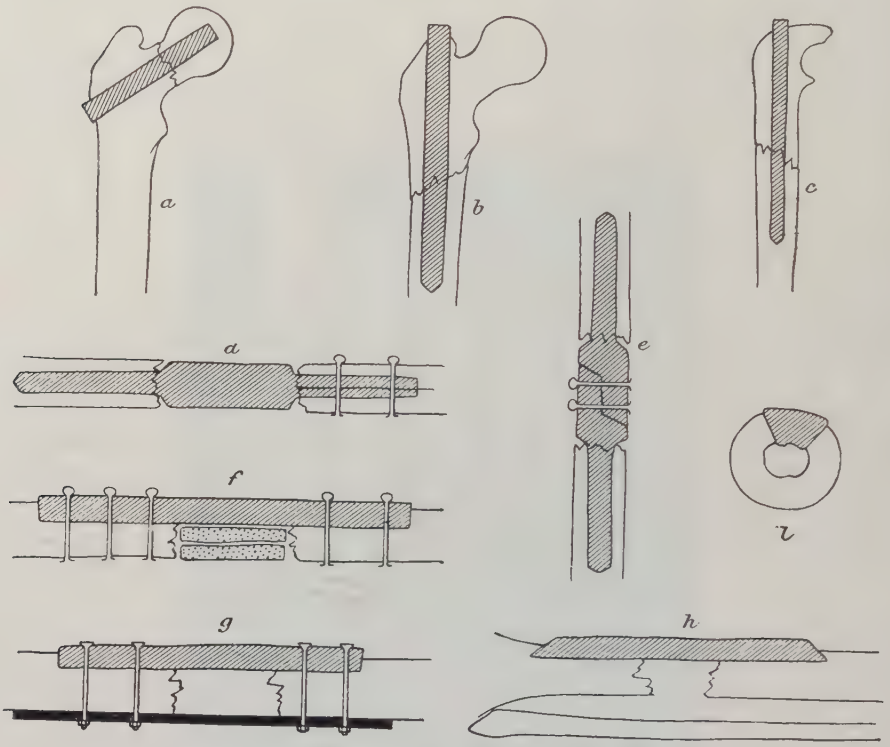


Fig. 1708.—Showing methods of fixing and fitting a graft: *a*, Graft driven into trochanter, neck, and head of femur; *b*, graft driven into medulla of upper third of femur from trochanter; *c*, graft driven into medulla of proximal part of ulna from olecranon; *d*, graft tightly fitted into both fragments of a fracture. At one end the shaft has been split for its reception, and then pinned together; *e*, graft tightly fitted into both fragments of a fracture. The graft has been cut by a fret-saw in a Z manner and pinned together afterward; *f*, graft fitted as a cortical strut and fixed by pins. The fragments marked by dots have been cut from the shaft and used to fill up the gap between the main ends of the bone; *g*, graft fitted as a cortical strut and bolted to a plate on the opposite side of the bone; *h*, inlay graft fitted and fixed without metallic sutures; *i*, section of the inlay graft, showing its wedge shape. (After Hey-Groves.)

holes are drilled (Figs. 1474, 1475), and silver wire is used in suturing the graft displaced, but attached posteriorly to the fragments after these have been properly fashioned. The soft parts are closed. This pedicled flap (Cole) is certainly in every way to be recommended. It has proved eminently successful in the hands of its originator.

The methods used by Billington and Round, and described on page 832, are worthy of serious consideration.

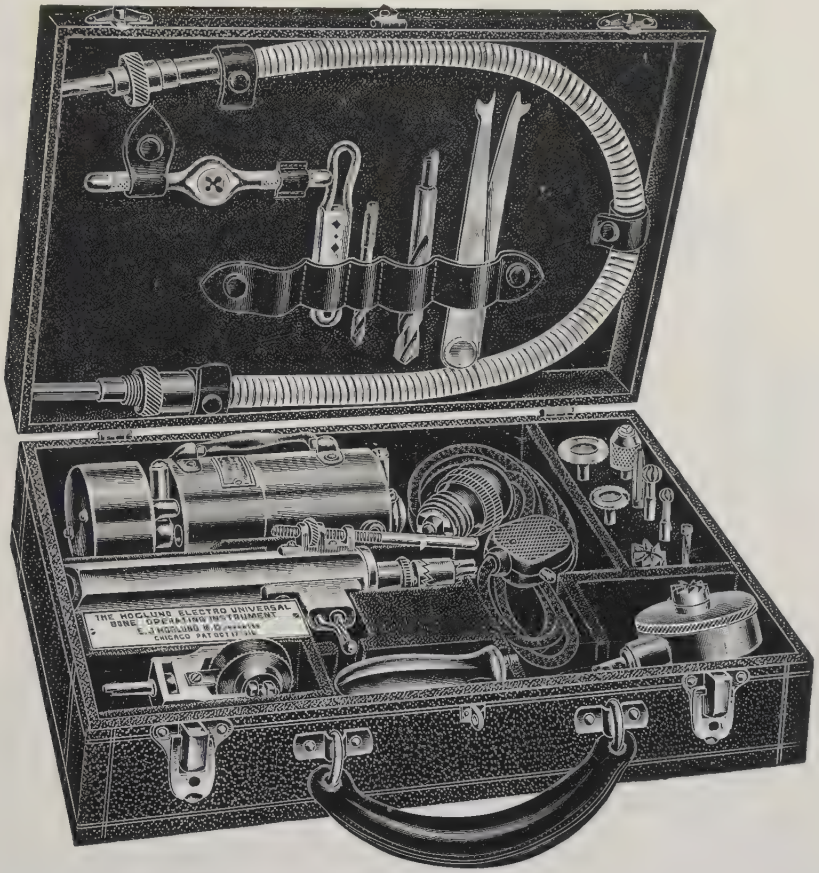


Fig. 1709.—Hoglund electro bone instrument. Note motor in left-hand corner of case. Note flexible shaft in cover of case.

The *twin saw* is so constructed that it runs parallel to the long axis of the handle. This is especially desirable for inlay or intramedullary bone splints on the femur where the cutting has to be done at the bottom of a deep wound. The saw in its holding frame is only 1½ inches wide over all. It can be adjusted for making the inlay fit the groove with absolute accuracy. The improvement is that the saws cannot be placed wrong if taken apart, which should not be done.

A new design of *doweling attachment* has been added, by which large and small bone-pegs and dowels may be rapidly and accurately cut. These small pegs may be converted immediately into bone-screws by means of a die which is furnished with the outfit and the recipient bone can be threaded by appropiate tap. *Drills* of proper size are included in the set. These pegs and screws are of value in many varieties of oblique and spiral fractures and in fractures of the neck of the humerus and femur or olecranon. There is also supplied a universal chuck to be used for any small drills.

The *mechanical clutch in the handle*, which had a tendency to slide if not properly depressed when in use, has been replaced by a straight shaft in the handle and a controlling switch at the motor which can be turned off and on by an assistant, or a foot switch can be supplied for use by the surgeon himself. The new design of a hexagon-shaped handle will insure a better hold when at work.

The *universal motor* for both direct and alternating current, 110 volts, has been improved by worm-gearing, running in hard grease, giving more power, less speed, and eliminates much of the noise. It adds nothing to the size of weight, which still remains 5 pounds. The greater power is of value in running the twin saw. The *teeth the of saws* are set so that they cut free. The *speed of the motor* is so adjusted that it is unnecessary to use water to prevent overheating the bone, though a few drops of water now and then may produce easier cutting, especially when the twin saw is used. The *flexible shaft* is enormously strong and will not *buckle* or *generate* heat.

A feature of instimable advantage in this instrument is the fact that the flexible shaft, the universal handle, and all of the accessories can be boiled and sterilized with other instruments in the ordinary way without the slightest damage.

Certain Facts of Importance in Connection with the Phenomena of Transplantation of Bone.—Present evidence points to the ultimate death of the entire bone-graft.

Replacement of bone depends upon the firm contact of graft and host bone as well as on the function or stress and strain of the part.

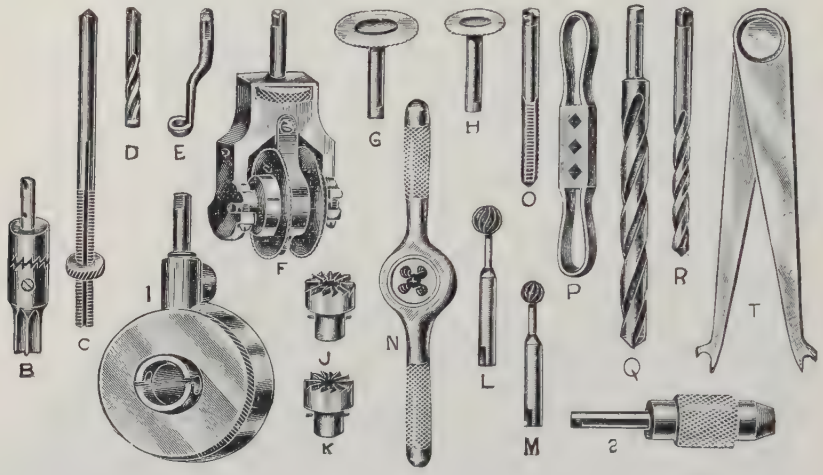


Fig. 1710.—Universal motor, 110 to 130 volt, D. C. and A. C., 25 to 60 cycle; universal hand piece flexible shaft. B, Automatic trephine. C, Trephine guard. D, Spiral osteotome. E, Spiral osteotome guard. F, Twin saw (spiral gear driven), cutting parallel to handle. G, Single circular saw, large, 1¼ inch. H, Single circular saw, small, ¾ inch. I, Dowel shaping instrument. J, Dowel reamer, ⅜ inch. K, Dowel-reamer, $\frac{3}{16}$ inch. L, Round burr, ⅜ inch. M, Round burr, ¼ inch. N, Die, $\frac{7}{16}$ inch, and holder. O, Tap, $\frac{7}{16}$ inch. P, Tap holder. Q, Twist drill, ⅜ inch. R, Twist drill, No. 25 for tap. S, Universal chuck for small drills. T, Combination caliper. U, Instrument case, leather and plush lined.

New bone appearing after a grafting operation is partly derived from the host bone, but largely from a change in the undifferentiated connective tissue about the transplant.

Physicochemical agents associated with the absorbing or disintegrating transplant seem to stimulate the growth of new bone.

No single element of the bone-graft is essential for successful transplantation. The endosteum and bone-marrow are of minor importance.

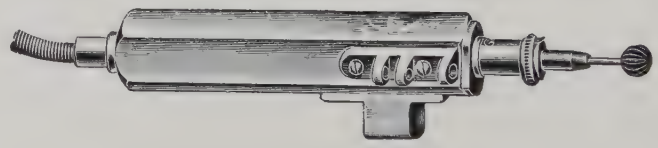


Fig. 1711.—For burring out diseased cavities, use one of the different ball-burrs (L) and (M) as needed, inserted in the universal holder.

The practical importance of the use of the periosteum is that early union of the graft with the surrounding tissues occurs and the process of orderly replacement of the transplant by bone is invited and facilitated.

A clinically successful result depends upon the persistence of the graft until its adequate replacement by the host takes place.

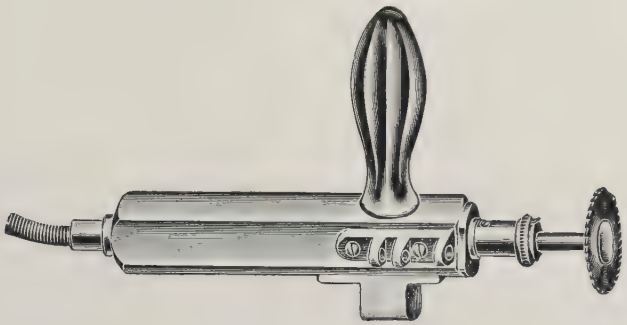


Fig. 1712.—The single saws (G) and (H) are used for intramedullary splints and inlays and also where the graft does not have to be fitted into a gutter. For example, in Pott's disease. The caliper (T) should be used to measure width and length. In fitting inlays with single saw, tip the saw slightly outward, making a bevel edge, thereby securing an easy fit of the bone-graft. The guard washer on the saw follows the contour of the surface of the bone, also it gives a steady feeling without any vibration to the handle.

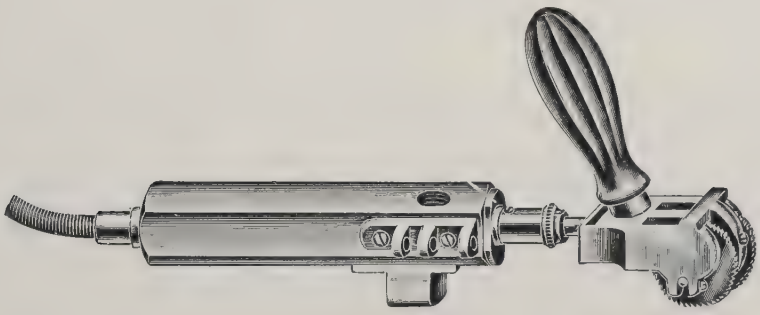


Fig. 1713.—The twin saw attachment (F), for intramedullary or inlay work, makes it possible to saw where there are heavy muscles and limited field to retract; for example, the femur. When using the twin saw for inlay work, first decide on the width of the bone-graft, then saw out a groove the desired length in the fractured bone; next set one of the saws a notch further out on the shaft where it is fastened by loosening and tightening the set screw in the collar of the saw. This will make the new graft fit absolutely snug in its new place. Several changes as to width can be made.

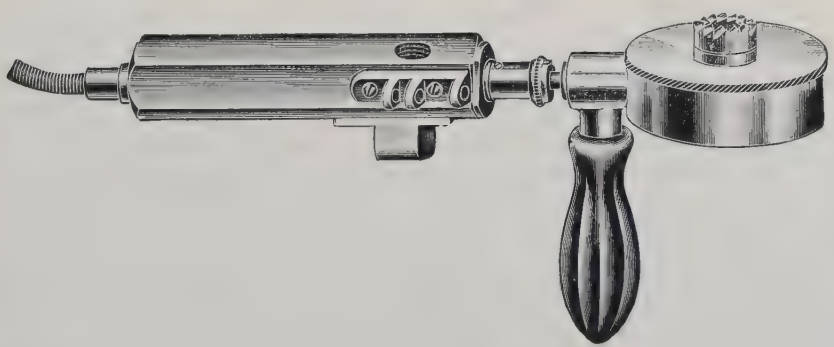


Fig. 1714.—Doweling attachment (I) with large and small dowel reamers (J) and (K). For making small bone-pegs saw out an additional strip of bone about $\frac{1}{16}$ inch wide, or utilize one part of bone taken out at the fracture by sawing it into two parts. Hold these bone strips with a hemostat, and with bone-cutting forceps make the peg a little pointed to fit the reamer at the start. Attach the dowel shaper instrument to the universal holder on the instrument and press gradually the bone strip down to the desired length. The small pegs can be threaded by screw plate N, and fitted into appropriate tapped holes by tap O, or driven in. The large bone-pegs are usually for fracture of the neck of the femur and are usually taken from the crest of the tibia and driven in after using the $\frac{3}{8}$-inch drill Q.

Counteracting all deforming tendencies, rigid asepsis, a careful operative technic, carefully thought out beforehand and adapted to the individual case, a wide opening of vascular bone, proper immobilization after operation, are all important factors in securing satisfactory results.

It is most important to reserve the bone-grafting operation for those cases in which it is really needed, and not to employ it indiscriminately.

Graft Fractures.—The *early* fractures occur after six to eight weeks. The site of fracture is ordinarily at one of the junctions of the graft with the host bone. It is due probably to inadequate contact originally between graft and host. Union is unlikely in this type of fracture.

The *late* fractures occur several months after the grafting operation. It has occurred as late as two years after operation. The site of fracture is usually about the middle of the graft. In these late cases the following is the story: The graft has successfully united at each end to the host bone. The limb is being used somewhat. An unusual strain fractures the graft. Some of these cases will unite after a prolonged period of immobilization.

A Study by McWilliams of Results Following Different Grafting Methods

Statistics from a study made by McWilliams of 1201 cases of results of grafting operations are as follows:

Bone-pegs, with 95.8 per cent. successes.

Osteoperiosteal method, 87.3 per cent. successes.

End-to-end method, 85.2 per cent. successes.

Inlay method, 83.6 per cent. successes.

Intramedullary method, 79.8 per cent. successes.

The total successes were 1017, 84.6 per cent.

The total failures were 184, 15.3 per cent.

From these figures the peg method seems to be the most successful.

Too much importance, McWilliams writes, attaches to the bone cell as the necessary element in bone regeneration. From all the available evidence Bancroft and I conclude that (see Chapter XXIX, p. 913) bone is mesoblastic in origin, and in its repair it is found that the calcium salts are deposited in the intracellular elements of connective tissue forming new bone. The connective-tissue cell then by metaplasia becomes a bone cell. Periosteum is a connective tissue and, hence, is prone to form bone, but it is not the only connective tissue that has this function.

Practically, when one considers the results of grafting with and without the periosteum attached, there is really very little difference to be seen. As good results are obtained without its presence as with it.

CHAPTER XXXV

PATHOLOGICAL FRACTURES

A. A STUDY OF SPECIAL MATERIAL

By Joseph Colt Bloodgood

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The completed chapter upon pathological fracture of bone cannot, of course, be written until a very large number of cases are exhaustively examined and fully recorded. This study has been made of a relatively large group—about 125 examples among 960 bone tumors. In addition, a study has been added of those diseases of bone which somewhat resemble clinically and roentgenologically bone tumors.

Is a Fracture Which Has Evidently Taken Place Through Diseased Bone Diagnostic?—It is not. The diagnosis must be based upon the *x*-ray picture and other data of the history and examination, and is apparently very little influenced by the clinical symptom of fracture or the evidences of fracture in the roentgenogram.

One would naturally expect to observe fracture in diseases of bone in which there is destruction of bone.

Incidence of Fracture.—Simply taking the total number of cases of benign and malignant bone tumors, the incidence of fracture is about 12 per cent., and these fractures may be divided into four groups, those having a

I. History of previous fracture which has united.
II. History of fracture with non-union.
III. Definite symptoms of bone disease with the later development of fracture.
IV. Fracture as the symptom of onset.

The incidence of fracture in diseases of bone, such as tuberculosis, osteomyelitis, syphilitic periostitis, Paget's disease, rickets, and the other less frequent diseases of a single bone or of the skeleton, is distinctly smaller than in bone tumors, whether benign or malignant. I have been unable to present the exact figures because of the difficulty of getting the total number of the different types of bone diseases. Practically every example of bone tumor—whether benign or malignant—reaches the surgical pathological laboratory. In many examples of other diseases of bone there is no operation and no tissue removed, so that exact figures as to the incidence of fracture to be compared with that occurring in tumors is not available, but it is distinctly smaller.

Incidence of Fracture in Bone Tumors.—It is interesting to compare, first, the 55 examples of fracture among 144 cases of bone cysts—a percentage of 38, with 9 pathologic fractures among 144 examples of the giant-cell tumor,

or 6 per cent. In both of these diseases there is complete destruction of the cancellous bone, with thinning and expansion of the cortical bone. Yet in the bone cyst a history of fracture and refracture with healing, fracture as a symptom of onset and fracture after symptoms, is common, while in the giant-cell tumor it is rare. The only explanation is that the giant-cell tumor involves the *epiphysis*, and the ostitis fibrosa which produces the cyst or fibrous tissue involves the *shaft*. This is true in all diseases of bone—pathological fracture is more common in the shaft than in the epiphysis and more common in the pipe bone, whether small or large, than in other types of bone. The explanation of this is purely mechanical. The location of the fracture in the shaft or epiphysis or in any other type of bone is not diagnostic.

One would naturally expect that diseases of bone which produce new bone and with little or no bone destruction would show few examples of fracture. In 214 cases of exostoses there were but 3 fractures (Fig. 1716), about 1 per cent., and the adequate explanation was trauma and not the disease. The incidence of fracture in multiple myeloma and metastatic tumors is greater than in primary sarcoma, because the myeloma and metastatic carcinoma usually attack the shaft and produce bone destruction. The percentage varies from 21 in metastatic tumors to 25 in myeloma. All involved the shaft of long pipe bones.

Primary sarcoma of bone with rare exceptions does not begin as a central lesion, as is distinctly the case in the bone cyst, the giant-cell tumor, the myeloma, and the metastatic carcinoma. It begins as a diffuse or periosteal involvement, and often bone formation in the onset is as marked as bone destruction, and although the shaft is most frequently involved, fractures do not occur very frequently, and then only after symptoms have been present some time. Our records show 25 examples of pathological fracture, or 6 per cent., among 287 examples of primary sarcoma, and with very few exceptions the shaft of a pipe bone was involved.

I. **History of Fracture.**—This study has an interesting medicolegal feature of practical importance in accident insurance and workmen's compensation cases. The general conclusion is that a definite fracture which heals spontaneously and after which the patient is apparently well, excludes malignant disease, but not necessarily a benign tumor, such as a bone cyst, a chondroma, or a giant-cell tumor.

Among the 55 examples of *benign bone cysts*, in 14—about one-fourth—there is a definite history of fracture and refracture with union. But there is every reason to believe that in these cases the cyst was present at the time of the first fracture and the fracture was not the cause of the cyst. As a rule, fracture in a bone cyst is followed by complete ossification, but in some instances in which the cyst is large and the fracture small the fracture may heal, but the cyst may not ossify. This has been clearly proved in recent cases by Roentgen-ray studies. If the fracture is extensive or comminuted, or if at the operation the bone shell is crushed, the ossification of the bone cyst is rapid and complete, and permanent. We therefore have no evidence that

fracture produces the bone cyst. This positive statement is made without taking space here to give all the evidence.

In the *giant-cell tumor* a history of fracture has been observed but once among the 9 examples of fracture in this group, and in this case we have no positive proof that the giant-cell tumor was present at the time of the first fracture. There was a fracture of the lower end of the radius like a Colles fracture; no *x*-rays were taken; complete union and restoration of function followed. Some months later the swelling of the tumor became apparent. But when we study all the evidence of the giant-cell tumors the findings show a remarkable contrast with that of the bone cysts. There is every evidence to indicate that the central giant-cell tumor is the definite result of a trauma, perhaps a hemorrhage into the marrow and cancellous bone. This hematoma, confined by the bone shell of the cortical layer, interferes with ossification, and the granulation tumor develops. In fracture there is an opportunity for the escape of blood and, theoretically, conditions are better for ossification. But the practical point is this: The relation between trauma and the development of a giant-cell tumor is as clearly brought out as between trauma and sarcoma, while it is absent in the bone cyst, the chondroma, the myxoma, the myeloma, and the metastatic tumor. The type of the trauma in the giant-cell tumor and the sarcoma is a contusion of bone without any clinical evidence of fracture, and in two of the examples of giant-cell tumor I have Roentgen rays directly after the contusion, and these exclude fracture and evidence of tumor. In later Roentgen rays the development of the tumor is clearly pictured.

In *sarcoma of bone* among the 25 examples of fracture, in 5 there is a history of fracture, but there is no evidence that the malignant tumor was present at the time of the fracture, so we have no positive evidence of a definite ossification of a fracture through a sarcoma of bone. Codman is rather of the opinion that this may have taken place in one of the cases registered from the Peter Bent Brigham Hospital. There is no question that the man had a fracture of the femur in December, 1919, but the *x*-ray showed no bone disease. There was ossification. Tumor formation was not observed until eleven months later. There are 3 such cases in my list. They all suggest that the sarcoma that developed after the trauma were rare examples of the formation of a sarcoma at the site of a fracture. In two instances there were numerous refractures with ossification, and the careful study of these 2 cases gives no evidence that the sarcoma was present at the time of the fractures, but they are examples of malignant disease secondary to repeated trauma.

Therefore, if there is a history of fracture with ossification and later a bone cyst appears, our evidence indicates that the bone cyst was probably present before the fracture. This would be true for chondroma also. But if the disease proves to be giant-cell tumor or sarcoma the chances are that, although the fracture healed, this trauma was responsible for the development of the pathological process.

The older literature would give the impression that ossification not infrequently took place in malignant disease of bone. I am inclined to think

it can be explained by the fact that these cases so recorded were either bone cysts or giant-cell tumors, or that their conclusions that the disease was present at the time of the fracture were incorrect.

Healing of Fracture in Sarcoma.—Among the 25 examples of fracture in sarcoma 4 can be excluded as definite examples of fracture through the normal bone which has ossified and in which the sarcoma has developed later. Of the remaining 21 cases, in 19 we can exclude ossification of the fracture, although ossification in some types of sarcoma takes place without fracture and without *x*-ray treatment. There are 2 cases in which it is suggestive that ossification may have taken place in fracture. In one of these I am unable to confirm the diagnosis because the decalcification is not yet finished.

The data in one case were referred to me by Chaddick, of Quincy, Illinois. The fracture took place in July, 1924, but the Roentgen ray suggests some disease of bone of the osteoporosis (destructive) type at the time of fracture. Both clinically and from the Roentgen ray ossification took place. This patient was again observed in March, 1925—nine months later. The Roentgen ray then showed areas of bone destruction in the shaft of the femur in an ossified fracture. The leg was amputated. The specimen suggests sclerosing sarcoma, but as yet we have no microscopical proof. Should this prove to be sarcoma, it will be a positive example of ossification in sarcoma of bone in which there was no Roentgen-ray treatment.

The second case is one recorded by Simmons, of Boston. At the time of the examination the female, aged twelve, a mental defective, had evidence of a fracture and a tumor in the shaft of the humerus. The *x*-ray showed bone destruction, fracture, and periosteal bone formation. Simmons is of the opinion that there was partial ossification of the fracture as shown in the *x*-ray and in the specimen obtained by amputation. I am rather inclined to the opinion that much of the bone formation is associated with the neoplasm and not with the fracture which is largely through the area of bone destruction.

Accepting these 2 cases as examples of ossification of fracture in sarcoma, we can appreciate its rarity—2 out of 21 cases, about 10 per cent.

II. **History of Fracture With Non-union.**—If an *x*-ray is taken at the time of fracture, the subsequent non-union or failure of complete ossification is not an indication of either a bone disease or a bone tumor, but of some local or general defect which interferes with the function of the osteoblasts. I will not discuss this question. This chapter deals with fractures in which the *x*-ray clearly pictures a previous disease of the bone. Non-union after fractures in bone cysts is very rare. Figures 1723 and 1724 represent our only example. Ossification of a bone cyst is very rapid if the fracture is extensive or comminuted. If there is no fracture or but a slight fracture, or an operation with but slight fracture, complete ossification may be retarded and there may be a subsequent fracture which completes the healing. If not, operation is as much indicated for retarded ossification or the lack of it in the bone cyst as for definite non-union of a fracture.

In giant-cell tumors, in chondromas, we may expect ossification of the fractured bone shell, but not of the central tumor. I have already called attention to the fact that, in the giant-cell tumor, the function of the osteoblasts is apparently arrested. For this reason after the central tumor has been curetted complete ossification is hastened by bone transplantation. The graft should be autogenous.

In multiple myeloma there is one example of ossification of the fractured bone shell (Fig. 1717), and of temporary ossification of the bone shell in metastatic hypernephroma (Fig. 1718). In all other cases of myeloma and metastatic tumors there has so far been non-union. In 19 primary sarcomas there was non-union of the fracture. In 2 of these there was possibly ossification. In sarcoma bone formation and bone destruction may go on at the same time. The destruction may later lead to fracture, and the old bone formation may suggest attempted ossification.

As tuberculosis attacks the epiphysis and not the shaft, we would not expect fracture. In the few examples of tuberculosis of the shaft I have no instances of fracture. I therefore had no opportunity to study the behavior of ossification of a fracture through tubercular bone. But judging from our experience with operation (resections of joints) we should expect ossification, although retarded, especially if tuberculosis of the bone is associated with the osteoporosis of non-use. I have no examples of fracture through syphilitic periostitis. The few examples of fracture through osteomyelitis have subsequently healed; union was usually retarded (Figs. 1725–1727).

The few examples of fracture through a bone the seat of Paget's disease have healed normally. If there was non-union of a fracture in a bone evidently an example of Paget's disease, I would be suspicious of secondary sarcoma and amputate at once. The examples of fracture in general disease of the skeleton, for example, ostitis fibrosa, rickets, and the rarer types, are of no importance from the diagnostic standpoint. As a rule, the fracture heals, but has no influence on the general disease of the skeleton.

We may therefore say that non-union, like fracture, of itself is not of great help in diagnosis.

III. **Symptoms of the Bone Lesion, Then Fracture.**—This is the common sequence of events in both benign and malignant neoplasms and in the different types of bone diseases. In recent years since the educated public pays more attention to pain, limp, and swelling in the region of bones and joints, and since their family physicians advise them to have a Roentgen-ray examination, the number of cases in which pathological fracture is the symptom of onset is growing less and the group in which the fracture is observed after symptoms is growing larger. If these cases are properly treated, fracture after definite symptoms of a bone lesion should also become less frequent.

As I have already tried to emphasize, the fracture which is observed after other symptoms have become manifest is not particularly helpful in the diagnosis, but if the patient has not sought advice before, the fracture will bring him under observation and treatment.

The treatment of a fracture in any bone disease does not differ in the two groups—the one under discussion and the fourth group, in which the fracture is the symptom of onset.

Fractures of all types play the prominent part in the history of the bone cyst. When I first studied a smaller group the incidence of fracture was 50 per cent., now it has been reduced to 38 per cent. This can only be explained by the fact that parents pay more attention to the complaints of the child when there is pain, swelling or limp, and Roentgen rays are immediately taken. But this study of the fracture in the bone cyst has led to the most important part of the operative technic—the rapid permanent cure rests more upon fracture and, in some instances, crushing of the bone shell, than upon the evacuation of the fluid, or the removal of the fibrous, leathery connective-tissue lining the bone shell.

I may cite an illustrative case. A child of nine developed a limp with a little discomfort in the region of the right hip. An *x*-ray revealed a cyst in the shaft of the femur below the level of the lesser trochanter. The bone shell was intact. Under rest and crutches for two months there was some little ossification. Then the child was allowed to return to school and play. As Roentgen rays were taken the original ossification disappeared. About one year after the first Roentgen ray I advised operation. Before the receipt of this letter fracture occurred; fortunately it was comminuted. There was complete ossification in three weeks, and there has been no recurrence in ten years. This case demonstrates that when one observes a bone cyst without fracture and it does not ossify quickly under observation, nothing is gained by delay, but it is important to remember that many small bone cysts completely ossify without fracture. The cause of the cyst and the cause of the spontaneous ossification are not yet known. It is also important to bear in mind that the diagnostic signs of the bone cyst are not so much the incidence of fracture or its position in the shaft, but the youthful age of the patient. If the patient is over twenty and the lesion is central in the shaft, whether there is fracture or not and whether the fracture is the symptom of onset or not, there is still a possibility of a latent unossified bone cyst. But the probabilities are that the central lesion is a chondroma, myxoma, myeloma, or metastatic tumor.

I have already published a study demonstrating that the bone shell in the giant-cell tumor may be perforated, fractured, or destroyed, and this occurrence, easily appreciated in the Roentgen ray, is not an indication of greater malignancy. In only 1 out of 9 cases of giant-cell tumor with fracture has the fracture been the symptom of onset, so that fracture in the giant-cell tumor, like perforation, thinning, and destruction of the bone shell can usually be explained by delay on the part of the patient or the physician. But in one instance of giant-cell tumor the bone shell may be destroyed within six months, while in another it may still be intact in six years. The point to remember is that the better the bone shell is preserved, the better the opportunity to restore the involved bone to full function. I have already noted that we do not expect ossification in the giant-cell tumor except now and

then in the line of fracture. Roentgen-ray treatment seems to retard the growth of the giant-cell tumor, and thus prevents perforation, destruction, and fracture of the bone shell. But up to the present time I have not a single example of ossification of the giant-cell tumor after prolonged Roentgen-ray or radium treatment.[1]

In the sarcoma of bone, with the rarest exceptions, the fracture is secondary. As a rule, fracture is associated with the late stages of the disease, whether the lesion be of the shaft or the epiphysis. Up to the present time no patient with sarcoma of bone and fracture treated by amputation or any other method has lived five years.

In myeloma all the fractures, 5 out of 24 cases, occurred after there were other evidences of disease, and even in metastatic tumors 15 out of the 18 cases had definite symptoms of the bone disease before the fracture occurred.

What Can We Do to Prevent Fracture When There is Evidence of Some Bone Lesion?—In bone cysts it is a happy occurrence. In giant-cell tumors it is due to delay or neglect. It is my opinion that in sarcoma, if one has decided not to amputate or resect, but to use Roentgen-ray or radium treatment, fracture can be prevented by rest, crutches, or fixation while the limb is being irradiated, and should Roentgen-ray studies show further increasing bone destruction, then we know that radiation is having no effect and resection or amputation must be resorted to, at least to give the patient comfort for the time he has to live. In multiple myeloma I have no evidence of the value of radiation or of any treatment that prevents the ultimate death of the patient.

Metastatic carcinoma is too large a chapter to consider here, but I have just observed a case which suggests that perhaps the use of crutches might have prevented pathological fracture. This patient had multiple metastases to the pelvis and upper end of femur with marked sciatica. Roentgen-ray treatment relieved the sciatica, so the patient could walk better. There is every evidence that the radiations over the upper end of the femur were not as intense as they should have been. One month after the last Roentgen-ray treatment while the patient was walking about her room a fracture occurred below the trochanter. In a second patient with a more extensive bone destruction of the upper end of the femur in which there was no involvement of the pelvis and no sciatica, fracture did not occur in the six months during which the patient walked with crutches before she died. This patient received radiations over the femur and protection from the use of crutches. I know that in my own clinic I am seeing metastatic carcinoma to bone more and more frequently and before fracture. There is, therefore, an opportunity for a study to find out what can be done. At the present time the patients should receive radiations. When the spine is markedly involved there should be, in addition, fixation in a jacket. If one of the long pipe bones shows much destruction, there should be fixation in splints or, for the lower extremity,

[1] Since the above was written I have seen Roentgen rays of giant-cell tumors in which a partial destruction of the bone shell has ossified after Roentgen-ray treatment—evidence which favors, at least as a preliminary measure, Roentgen-ray treatment of these tumors.

the additional protection of crutches. In all central tumors with fracture, whether in the shaft or in the epiphysis, it might be wise to use radiation except when in the shaft of a child under eighteen. Here it is unnecessary.

IV. **Fracture as the Symptom of Onset.**—As stated before, this is becoming less common. In the chondroma of the phalanges of toes and fingers and of the metacarpal and metatarsal bones fracture as the symptom of onset is rare and usually occurs in the phalanx of the toe or in the metatarsal bones. If left alone, healing takes place but the fracture has no effect on the chondroma.

I am inclined to the opinion that in the bone-cyst fracture as the first definite symptoms will remain, as it is, the most frequent occurrence in all types of bone lesions, and when the patient is young—under eighteen—and the lesion is in the shaft and fracture is the first symptom, the diagnosis should be as certain as that complete ossification and cure is to follow the fracture. Yet, it has been very difficult to broadcast to the profession this important bit of correct information. I have already noted that as a symptom of onset in giant-cell tumor fracture has been observed but once in 144 examples of the central giant-cell tumor, and in 9 instances of fracture.

In sarcoma among 287 cases fracture has been noted 25 times. In only 2 of them has it been the symptom of onset.

In one of these cases it is very possible that the patient had symptoms first. But as recorded, it is stated that a man of sixty received a trauma to the humerus in the region of the upper end. It was treated for fracture with a plaster dressing. There was non-union. Two months later a Roentgen ray, then amputation, then death.

In the second case, observed by Simmons of Boston, and already referred to, it is stated that the symptoms had been present but ten days after a trauma, but the examination revealed both, the fracture and the tumor.

The diagnosis of bone lesions difficult to diagnose at the present time rests upon verified and carefully studied definite cases. With few exceptions general statements are apt to be inaccurate or misleading.

Excessive Ossification of Fracture Suggesting Periosteal Ossifying Sarcoma.—Figure 1715 shows a lesion of the shaft of the second metatarsal which was sent to me with the possible diagnosis of sarcoma in 1923. How shall we recognize fracture and exclude sarcoma? Periosteal sarcoma of a metatarsal or metacarpal bone is not recorded in my series. Two bones are involved in the *x*-ray—the third metatarsal very slightly. The new periosteal bone formation about the second metatarsal has the appearance of benignancy rather than malignancy. The changes in the shaft are not distinctly those of fracture. There is evidently a healed fracture of the third metatarsal without callous formation. If the lesion in the *x*-ray of the second metatarsal were situated on a long pipe bone, it would be difficult to differentiate from an ossifying periosteal sclerosing sarcoma. In this case the patient did not remember an injury, but after eight months of lameness this Roentgen ray was taken. The condition, clinically and in the Roentgen ray, disappeared under rest treatment.

There is a second similar case involving a metatarsal, with practically identical Roentgen ray and history.

These are the only 2 cases of fractures which have come under my observation and in which sarcoma was diagnosed. As a rule, there is little

Fig. 1715.—Excessive ossification, fracture of metatarsal suggesting sclerosing sarcoma.

difficulty in distinguishing the normal and excessive callous formation associated with all types of fracture in which the fragments are in normal or abnormal position. We are also helped by the fact already recorded that

Fig. 1716.—Fracture in pedicle of an exostosis.

malignant disease is rarely associated with fracture, except in metastatic carcinoma and multiple myeloma.

Fracture in Exostosis.—Figure 1716 pictures the bone formation, the pedicle attachment of which has been broken from the pubic bone. The patient was

Fig. 1717.—Ossification of the bone shell of a multiple myeloma, but no ossification of the central lesion.

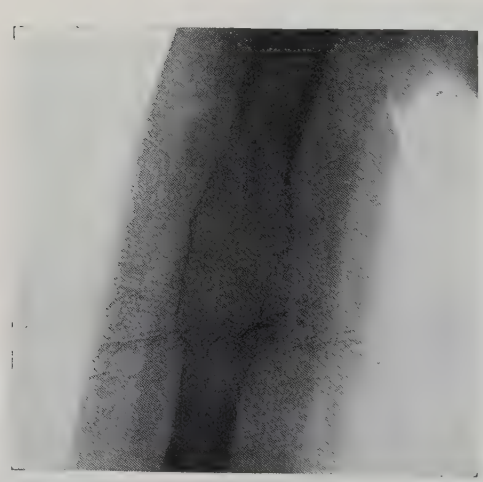


Fig. 1718.—Ossification of the bone shell of a metastatic hypernephroma with no ossification of the central lesion (see Fig. 1719).

Fig. 1719.—Destruction of the bone shell after its fracture had ossified, in metastatic hypernephroma. This *x*-ray taken two months after the one shown in Fig. 1718.

a rider and did not know that he had an exostosis of the ossifying periostitis or myositis type until he fell and struck the adductor muscle. Then there was pain and tenderness, the *x*-ray was taken, and this bone could be palpated. Nothing was done; the symptoms subsided, but the bone formation remains.

History of Fracture With Healing.—Figure 1717 pictures the healing, with deformity, of the shaft of the femur below the trochanter, and we can easily see a definite central destructive lesion with an intact bone shell. As the patient is an adult the age is against bone cyst, although the healing of the fracture would suggest a latent bone cyst. Subsequent events proved the disease to be multiple myeloma. The patient was seventy-one and the symptom of onset was a fracture. It was treated in plaster and healed. Subsequent *x*-rays found multiple lesions, and the autopsy revealed multiple myeloma.

Figure 1718 is the *x*-ray of the shaft of the humerus in an adult after a fracture which was the symptom of onset. The first *x*-ray taken directly after the injury was identical with Fig. 1718, except the bone shell was fractured. Observe that it has healed. There was no other evidence to help in the diagnosis. The age of the patient was against a bone cyst; the healing of the fractured shell was against a metastatic tumor. The patient's general condition suggested some serious lesion. Under observation, within two months the bone shell began to disappear (Fig. 1719) and there was death from pneumonia, and the arm removed after death gave us an opportunity to demonstrate that the central lesion was a metastatic hypernephroma.

Figure 1720 pictures a fracture through a central bone lesion of the tibia and a fracture through the normal fibula at a higher level. The history when first sent to me with the *x*-ray stated that the first symptom was the fracture after a slight trauma in a woman aged forty, who was otherwise in perfect health. This age favored a chondroma, a myxoma, a myeloma, or a metastatic tumor. But later we learned that during childhood she had had difficulties with this bone. At the exploratory operation the lesion proved to be solid ostitis fibrosa and there was a rapid complete ossification within a few weeks after the operation, as shown in Fig. 1721, taken ten months after operation.

The comparison of Fig. 1717 with Figs. 1718 and 1720 will show the difficulty of the differential diagnosis of central lesions of the shaft of long pipe bones in adults whether there is fracture or not.

In the case shown in Fig. 1722 there were some symptoms—slight pain in the shoulder, but no evident swelling—until, after a trauma, there was intense pain, and the *x*-ray taken showed the central destructive lesion of the upper epiphysis of the humerus with some involvement of the marrow of the shaft and, at ×, a fracture of the bone shell. Under rest this healed, but without evidence of ossification of the central lesion. The epiphysis is rarely involved in the bone cyst; the giant-cell tumor usually involves the epiphysis, and the common age is over twenty. But I have observed in the epiphysis of the upper end of the humerus chondroma and

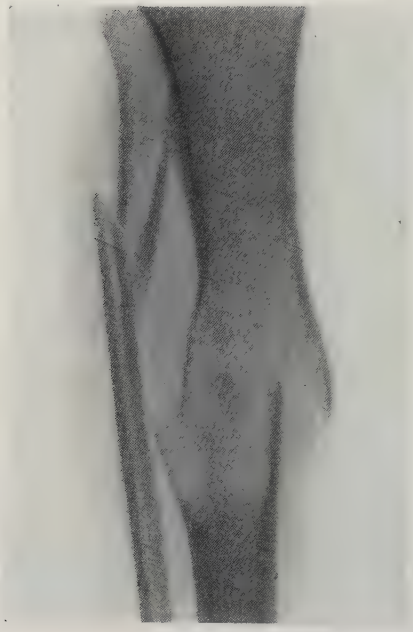


Fig. 1720.—Fracture through latent unossified bone cyst in adult aged forty and through normal fibula. For picture of healing see Fig. 1721.

Fig. 1721.—Ossification after fracture and operation in bone cyst (see Fig. 1720).

Fig. 1722.—Partial fracture through bone shell (at ×) of a giant-cell tumor.

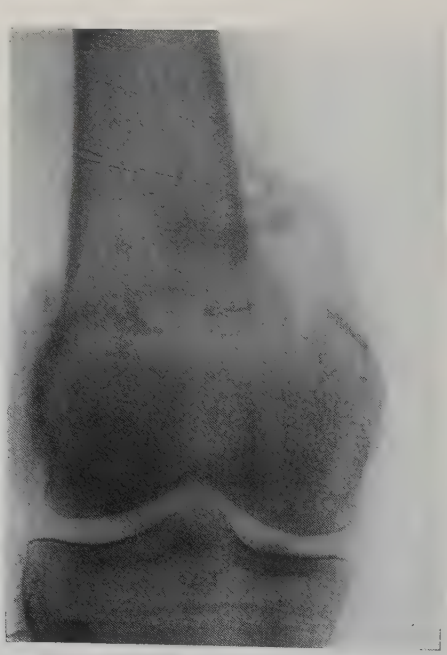


Fig. 1723.—Fracture through latent unossified bone cyst of lower end of femur. Note slight ossification at junction of fracture with shaft. For lateral view see Fig. 1724.

myxosarcoma. I have no evidence as to whether fractures would heal, but this case demonstrates that the bone shell of a giant-cell tumor may ossify, because at the exploratory operation it proved to be a giant-cell tumor.

History of Fracture With No Ossification.—Figures 1723 and 1724 are views of the lower end of the femur of a woman aged thirty-one who, without any previous symptoms, except pain, for one year, sustained a fracture after a slight trauma October 30, 1915. She was treated by extension and fixation. You will observe in Fig. 1723 some slight periosteal bone formation, but no

Fig. 1724.—Lateral view of lesion shown in Fig. 1723. Case incorrectly diagnosed sarcoma, followed by amputation.

Fig. 1725.—Sclerosing chronic non-suppurating osteomyelitis. Difficult to differentiate from ossifying syphilitic periostitis or sclerosing sarcoma with much periosteal ossification (see Figs. 1726 and 1727).

ossification of the central area of bone destruction in the epiphysis. In March, 1916, five months later, because of non-union, it was explored and a piece of tissue removed. I diagnosed the section fibrosarcoma and, when the patient was referred to me in May, 1916, amputated the femur. I have reported this case as central cystic sarcoma in the Journal of Radiology for March, 1920. This case was registered with Codman and accepted as a cured fibrosarcoma of bone. Some two years ago, on restudy, I felt convinced that it was a benign bone cyst. The bone shell was lined by the typical leathery connective tissue with a central cavity filled with

Fig. 1726.—Taken two years after Fig. 1724. Light area due to pus (see Fig. 1727).

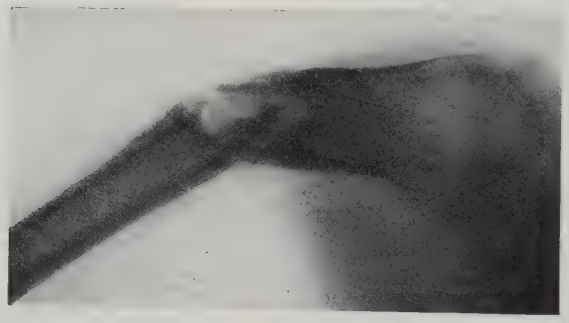


Fig. 1727.—Pathological fracture in osteomyelitis taken about five months after Fig. 1726.

Fig. 1728.—Pathological fracture in metastatic carcinoma (see Fig. 1729).

Fig. 1729.—This was taken two months after *x*-ray shown in Fig. 1728, and shows further bone destruction.

clear fluid. The patient is well today, nine years since operation. As stated before, it is unusual to observe a bone cyst in an adult and very unusual to find one in the epiphysis, and even more unusual not to have complete ossification follow the fracture. It is cases similar to this and diagnosed sarcoma that have lead to incorrect general statements in the literature.

Fracture in Osteomyelitis.—Figure 1725 pictures an ossifying lesion of the upper shaft of the humerus. The excessive periosteal bone formation is on the medial side. The mottled light areas may be the marrow shadow which has not been covered by periosteal bone formation, or they may be due to definite bone destruction. The boy was seventeen and within two months after a contusion of the arm this swelling of the upper one-third of the humerus appeared, with pain, and has been present seven months. This case was observed in November, 1920. The lesion was explored by Haggard, of Nashville, and the periosteal bone formation removed. The sections showed no evidence of sarcoma. About two years later (Fig. 1726) there was recurrent pain and some swelling, and the most marked feature of the *x*-ray now was the lighter area in the position of the old ossifying lesion. An exploratory operation now found pus which was drained. One month later there was a pathological fracture, and three and a half months later (Fig. 1727) there was still non-union with bending. At this stage I saw the patient for the first time and concluded that we were dealing with a chronic sclerosing osteomyelitis which at the time of Haggard's operation in 1920 was non-suppurating, and two years later, at the time of Fig. 1726, had changed to the suppurating type. Against malignancy the chief factor was suppuration. Figure 1727 represents an *x*-ray picture in which it is difficult to differentiate between sclerosing osteomyelitis, syphilitic periostitis, and sclerosing sarcoma. In some cases this can only be done by exploratory incision and biopsy. This case therefore illustrates that fracture may take place in chronic osteomyelitis, and there may be temporary non-union.

In this case ossification took place after about six months, during which there was partial fixation and use of the arm. At this time (1925), two years later, there is no recurrence.

Fracture in Metastatic Carcinoma—Non-union.—Figure 1728 illustrates a fracture in the shaft of the femur below the trochanters, and there is nothing in the *x*-ray which would allow a positive diagnosis. The adult age of the patient is against cyst. There is a little more ossification in the lighter area than one would expect in a cyst, a chondroma or a myxoma. That the patient had been operated on for cancer of the breast was the most suggestive evidence. A second *x*-ray taken within two months made the diagnosis of malignancy positive, because there was further bone destruction and no bone formation. This might take place in osteomyelitis (see Fig 1729).

B. GENERAL SUMMARY FOR STUDENTS

By Charles L. Scudder

Pathological fractures may be grouped according to Grunert into those in which the fragility of the bone is due to (A), a local lesion, and those in which the fragility is due to (B), a general disease.

(A) Fragility due to a local lesion.

1. Tumors in bone:
   - (*a*) Sarcoma, primary in bone.
   - (*b*) Hypernephroma
   - (*c*) Carcinoma
   - (*d*) Thyroid

   (*b*), (*c*), (*d*): all metastatic.
   - (*e*) Benign tumors: The enchondromata—bone cysts, echinococcus cysts. Multiple myelomata.
2. Infectious processes—osteomyelitis, either pyogenic or tubercular. Paget's disease.

(B) General diseases.

1. The neuropathies—tabes dorsalis; syringomyelia.
2. Senile changes.
3. Rachitis: Osteomalacia.

(C) Idiopathic fragility of bone.

Pathological fractures are due to local alterations in the strength of the bone occasioned by a new growth; an infectious or inflammatory process· changes in the bone associated with a general disease. The brittleness of the bone (osteopsathyrosis) is increased by these changes. The fracture may be symptomatic of the general or local disturbance. Trauma, even though it be slight, is necessary to cause the break; hence the term "spontaneous fracture" is improperly applied.

A. **"Symptomatic Fragilitas Ossium."**—(1) *Local changes in the bone may be due to* (*a*) *Tumors.*—Primary sarcoma is common in bone. Metastatic sarcoma is rarely found in bone. The order of frequency in the cases recorded of the appearance of sarcoma in the various long bones is as follows: in the femur in 56 per cent.; in the humerus in 21 per cent.; and in the tibia in 14 per cent.

(*b*) *Metastatic hypernephromata* may be the occasion of a fracture of one of the long bones, usually the femur or humerus. The pathological fracture may be the first evidence of the sarcoma or the hypernephroma. There is rarely union following fracture through either a sarcoma or a hypernephroma.

Myeloma may occasion a fracture of bone.

(*c*) *Metastatic Carcinoma.*—Skeletal carcinoma is very rarely the first sign of a primary carcinoma in the breast, thyroid, or prostate (Hawley). Metastatic carcinoma of the breast tends to produce bone destruction with little associated new bone formation, while carcinoma of the prostate produces in its metastasis little bone destruction and much new bone formation (Phemister). Primary carcinoma of the breast yields the largest number of

metastatic carcinomatous fractures. Many bony metastases come from prostatic cancer. The neck of the femur is the common site of the fracture. Union almost always takes place after fracture associated with metastatic carcinoma (Hawley). Bloodgood believes that union rarely follows metastatic carcinoma.

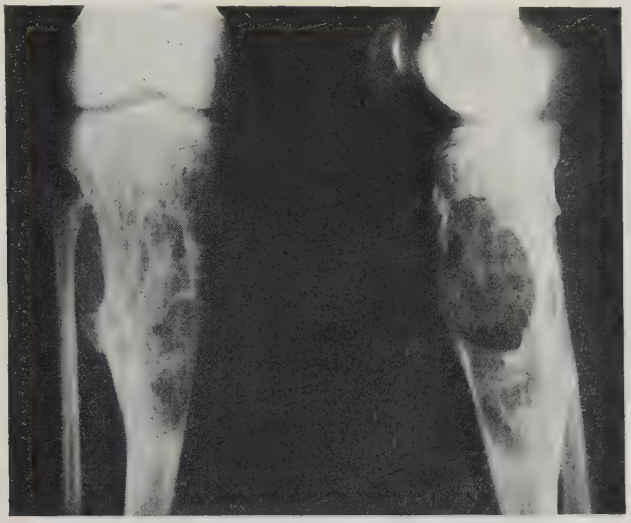


Fig. 1730.—A benign bone cyst of the tibia (George and Leonard).

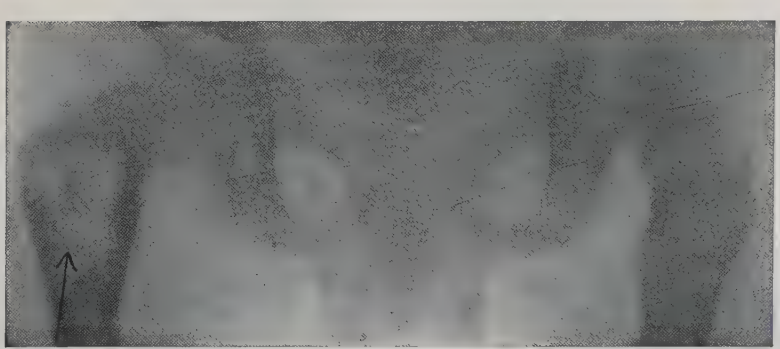


Fig. 1731.—Benign cyst of femur. Pathological fracture because of this benign cyst. Operation; interior of the cyst cleared away. Good bony union later (Balch).

(*d*) *Metastatic Thyroid Tumors.*—These tumors apparently arise from normal thyroid gland tissue. Blumer has analyzed all the cases (60) reported, and finds that the distribution of the metastases in bone is as follows:

Five per cent. appear in the humerus.
Ten per cent. appear in the femur.
Nine per cent. in the pelvic bones.
Sixteen per cent. in the vertebral bodies.
Thirty-eight per cent. in the bones of the cranium and face.

In two-thirds of the 60 metastatic cases the metastasis was a solitary one. The majority of the cases of thyroid metastases to bone have come from carcinoma of the thyroid (Bloodgood).

(*e*) *Benign bone cysts* are very commonly the seat of fracture. The femur is the common site of these cysts (Fig. 1731). A trivial injury in a healthy young adult followed by a fracture which is comparatively painless is strongly suggestive of a fracture through a cyst of the bone.

The natural tendency is for a bone cyst to extend through the shaft and always within the shaft.

Fig. 1732.—Cyst of upper end of humerus. Fracture through cyst.

An instructive case is that of a child with a fracture of the upper end of the humerus through a bone cyst. Operation done, cyst curetted, and lining membrane eliminated. Healing of wound, local extension of cyst downward into shaft—a few years subsequently fracture through the extension of the original cyst. Roentgen ray showed dense bone at the site of the original operation, and fracture and cystic changes *below* this point. The question arises, Should operation be done in this second local extension of the cyst or will the fracture of the cyst, by allowing the cyst contents to escape, invite healing of the cyst and the fracture?

The probability is that immobilization of this second cystic fracture will be followed by union and that the cyst will heal, unless, of course, there are unconnected cysts below the fracture line.

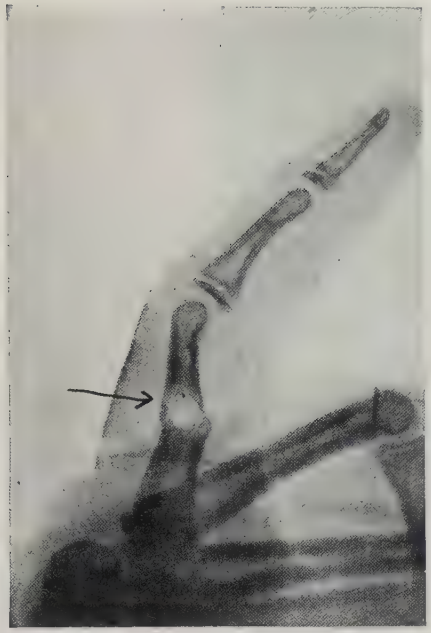


Fig. 1733.—Cyst of phalanx in a congenital syphilitic child. Fracture is seen through the cyst. Arrow points to cyst and fracture (Dodd).

Fig. 1734.—Cyst of phalanx; anteroposterior view. Arrow points to cyst (Dodd).

Fig. 1735.—Fracture of humerus through a simple bone cyst of shaft of humerus (G. W. Holmes).

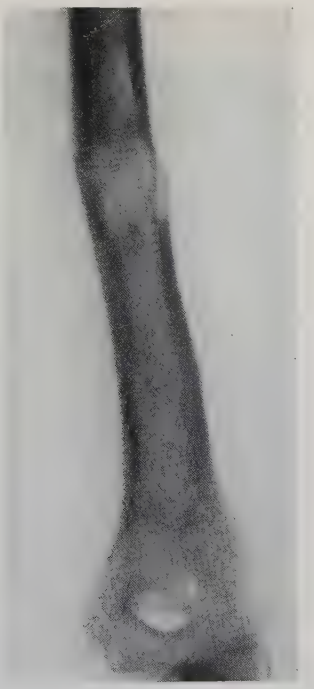


Fig. 1736.—Same case of simple bone cyst of humeral shaft as Fig. 1735 at a little later period (G. W. Holmes).

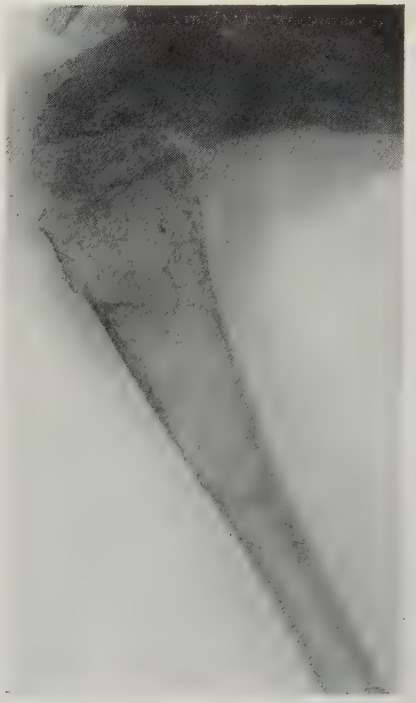


Fig. 1737.—A giant-cell tumor of the upper end of the humerus (G. **W. Holmes**).

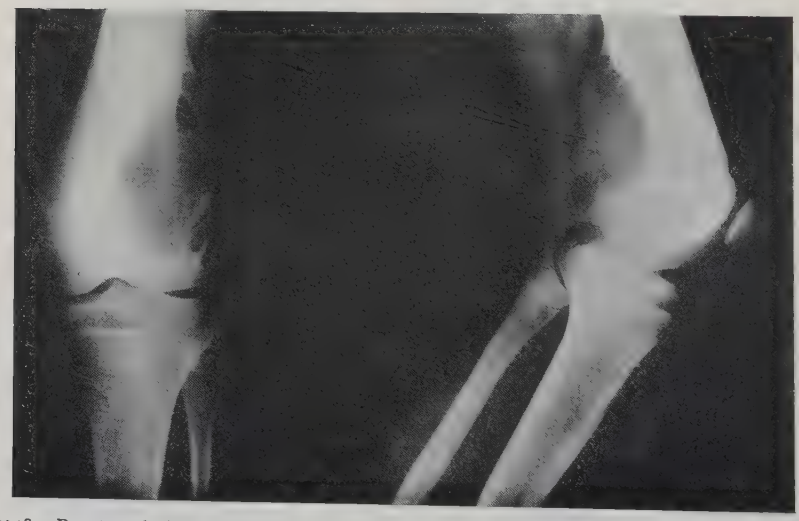


Fig. 1738.—Roentgenological appearances. Giant-cell tumor of the lower end of the femur (George and Leonard).

It is very important in persons reaching the age of forty-five and fifty years, who have a fracture through cystic disease of a long bone, to determine the exact character of the cyst.

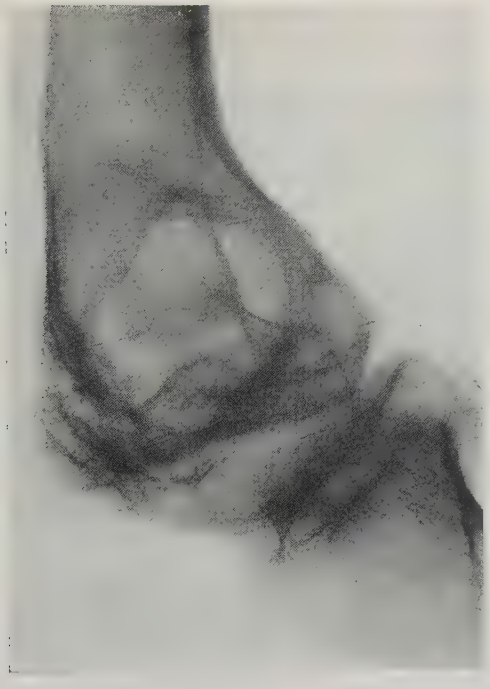


Fig. 1739.—Roentgenological appearances of a giant-cell tumor of the lower end of the femur with fracture (G. W. Holmes).

Fig. 1740.—Appearances of an osteochondroma of the tibia. Note evidences of slow growth.

Cysts of bone in adolescence and youth are invariably benign in character. In adult life the possibility of giant-cell sarcoma being present, or

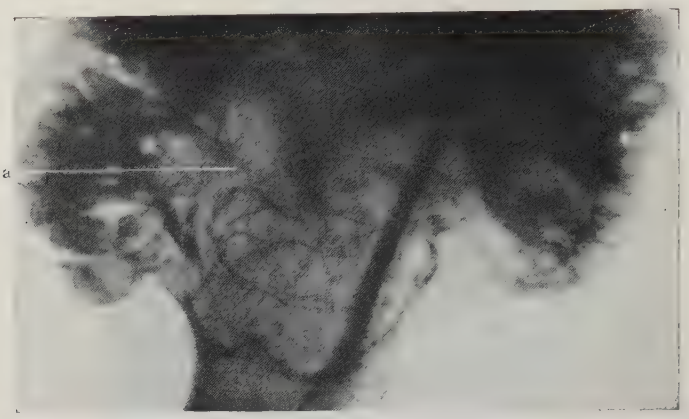


Fig. 1741.—An osteochondroma of the upper end of the humerus. *a*, Head of humerus, normal bone tissue. (G. W. Holmes.)

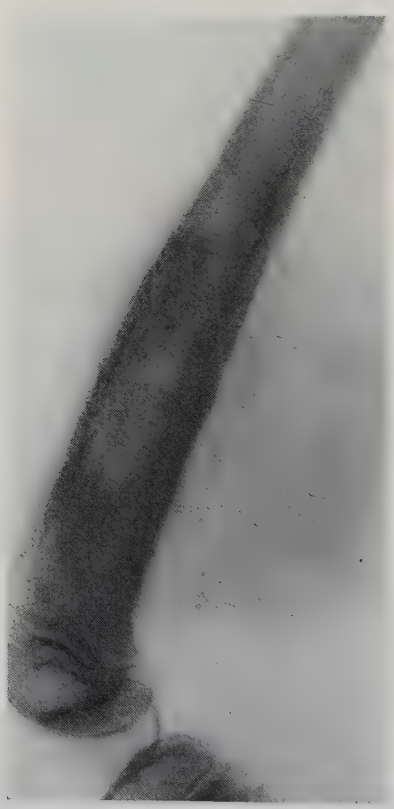


Fig. 1742.—Osteogenic sarcoma, periosteal type (G. W. Holmes).

even some generally malignant growth is to be entertained. Consequently, in the case of such cystic fractures in the adult the surgeon will be called

upon to decide for or against immediate operation to destroy the cyst—remove it.

Union of the fracture usually follows a fracture through a cyst wall. The fracture should be reduced and treated as if it were a closed and uncom-

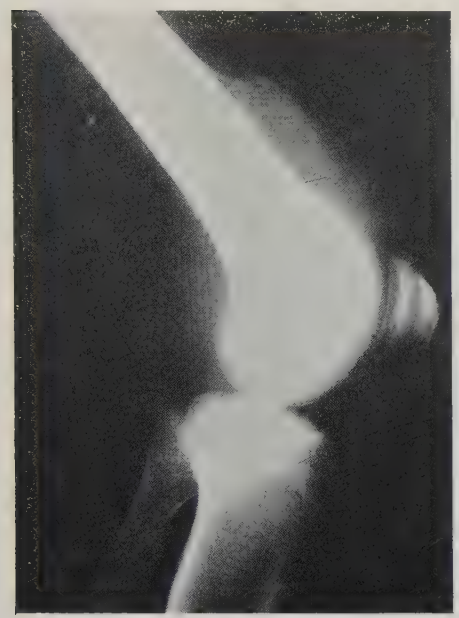


Fig. 1743.—Osteogenic sarcoma, periosteal type. Roentgenological appearances (George and Leonard).

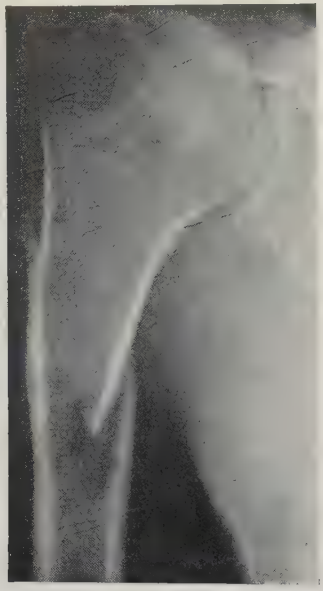


Fig. 1744.—Metastatic hypernephroma following a nephrectomy. Note fracture through the tumor (Richard Dresser, Massachusetts General Hospital).

plicated fracture. The best treatment for a bone cyst is a fracture. When the patient is under fifteen, and the shadow is central, suggesting bone cyst and involving the shaft, the diagnosis of bone cyst can be made because of

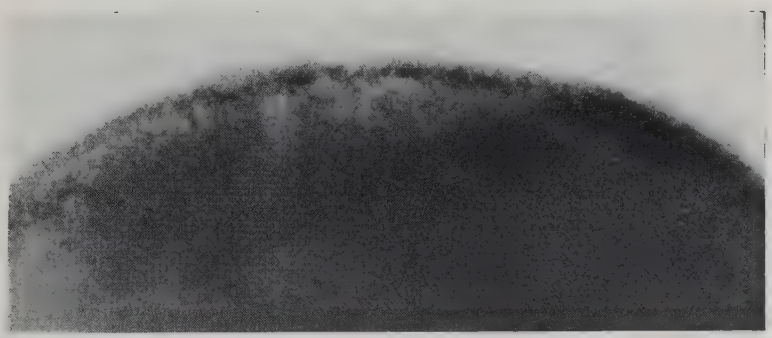


Fig. 1745.—Metastatic carcinoma of skull (G. W. Holmes).

the age of the patient and the position of the cyst. All thin-walled cysts in the shaft of the long bones, notably humerus and femur, under eighteen are usually benign. Thirty-eight per cent. of such long bone cysts have been asso-

ciated with fracture (Bloodgood). In patients older than eighteen the *x*-ray findings in the shaft may be due to chondroma, myxoma, metastatic tumor, or one of a multiple myeloma.

(2) *Local Changes in the Bone May Be Due to Inflammatory Processes.*—Infectious osteomyelitis sometimes, though rarely, gives rise to fracture. I record here one instance of this condition in a case of Painter (Figs. 1749–

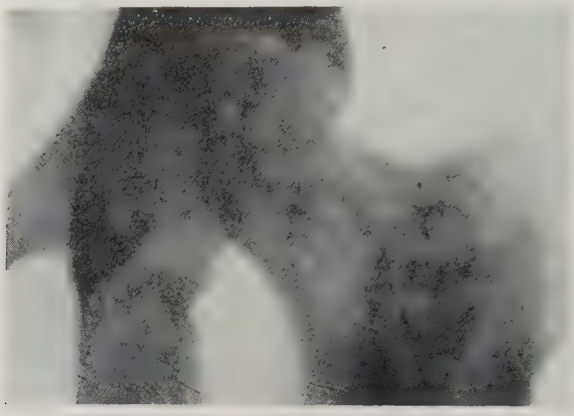


Fig. 1746.—Roentgenological appearances of metastatic carcinoma, hyperplastic type in femur and pelvis (G. W. Holmes).

1751). A girl two years old had a trivial fall and injured the right radius. The bone was broken. The injury was treated as if it were an ordinary fracture. No union resulted. A tender swelling soon after appeared within a centimeter of the tip of the radial styloid and spontaneously opened, discharging pus. An *x*-ray disclosed an osteomyelitic focus. Several opera-

Fig. 1747.—Roentgenological appearances of Paget's disease of upper end of the femur (G. W. Holmes).

tions were done for the removal of this focus and eventually the bones were united by suture.

In such cases of osteomyelitis the osteomyelitic focus should be treated upon general surgical principles (thorough drainage and the employment of

the endosteum and periosteum in the reparative process) and subsequently the resulting impairment of the bone cared for.

Tubercular osteomyelitis may allow of a fracture, but the sequence is a rare one (see Fig. 1759).

B. **General Diseases.**—*Syphilis* possibly increases the brittleness of bone so that fracture of bone may result from an ordinarily inadequate force. This is not proved.

Tabes Dorsalis.—Fracture may occur in any stage of the disease. It may be the first sign of the disease. The fracture is most often in the lower extremity. Pain is often absent, consequently, the fracture is overlooked. These fractures heal rather slowly, union is delayed, an excess of callus is formed.

Fig. 1748.—Roentgenological appearance of the shaft of the femur in a case of osteomalacia (G. W. Holmes).

Syringomyelia is accompanied by fracture of bone most often in the upper extremity.

Osteomalacia is accompanied by fracture. The *x*-rays (Figs. 1753, 1754) and the photograph (Fig. 1752) illustrate well the appearances in this disease. These are illustrations of the case of Painter. The cystic appearances and destruction of the cortex and medulla of the bone in this disease are well illustrated. The seat of fracture through these rarefied areas of the bone and the excessive amounts of callus developed at the site of the fracture are also well shown.

Osteopsathyrosis.—This is a term applied to the brittleness of bones, associated with multiple fractures. More than about 200 cases have been recorded. Yet the occurrence of the cases is rare. At the Massachusetts

General Hospital it was found that of 1610 long bone fractures, including the clavicle, only 2 cases were found due to fragilitas ossium. Cases arrange themselves into two groups, *a fetal type* found at birth or a little after birth. These cases do not usually survive after one year of life—ordinarily the mortality is reckoned on 100 per cent. Then there is a congenital type appearing at birth or a little later in childhood—such a congenital case continues to live and fractures may occur on into adult life.

Symptoms.—There is a tendency to frequent fractures of the long bones. The trauma producing the fractures is very slight. Simply lifting a forearm

Fig. 1749.—Osteomyelitis, fracture of radius (Painter).

Fig. 1750.—Osteomyelitis (Painter).

off the bed may result in a fracture of the arm. The signs of fracture will be an increased mobility of the part broken and slight deformity. There will be little or no pain, no tenderness, and very little swelling. The baby or infant will appear unwilling to use the broken extremity. The fractures in an individual case are often bilateral.

The long bones of the extremities, the clavicle, and the ribs are the common seats of fracture. The femur is the commonest bone broken (Locke).

The fractures are often subperiosteal (Kienbock). Union usually occurs in the fracture. Repair may be slow; on the other hand, exuberant callus is

occasionally seen. It is thought that a deficiency in calcium and phosphorus may exist in this condition of bone fragility. Important observations are now being made along this line.

Diagnosis.—The diagnosis is not difficult. There is no other congenital disease which is associated with multiple fractures. Rickets and syphilis associated with fractures, as they sometimes are at an early age, rarely if ever yield a case with more than two or three fractures. Rachitis is accompanied by fracture (see Fig. 1757).

Fig. 1751.—Osteomyelitis (Painter).

Fig. 1752.—A case of osteomalacia (Painter). Note supracondylar (fractures) deformities of the femora and similar deformity of forearm (see *x*-ray).

C. **"Idiopathic Fragilitas Ossium."**—Osteogenesis imperfecta (see Fig. 1761) (periosteal dysplasia).

Prognosis.—Simmons believes that the prognosis is, on the whole, rather unfavorable. The mortality in the first few months of life is extremely high, but in the milder cases there has been a distinct tendency as the child reaches puberty for the bones to become more normal, and the liability of fracture to cease, although in other cases the fractures have occurred with increasing frequency. In those cases where the condition has occurred in adults there may be a spontaneous cure, or the disease may progress from bad to worse.

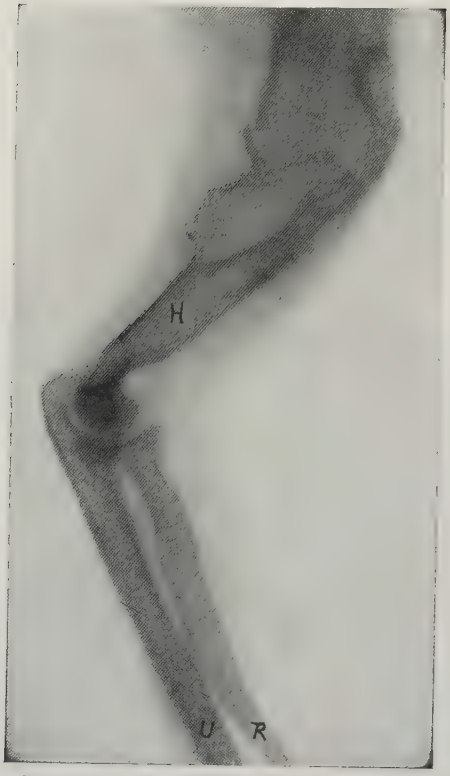


Fig. 1753.—*x*-Ray of osteomalacia, case of Painter. Note multiple fractures of radius and of the humerus (see Fig. 1752).

Fig. 1754.—*x*-Ray of Painter's case of osteomalacia. Note fracture of femur. Arrow points to seat of fracture (see Fig. 1752).

Fig. 1755.—Upper end of the femur in osteomalacia in a woman sixty years old.

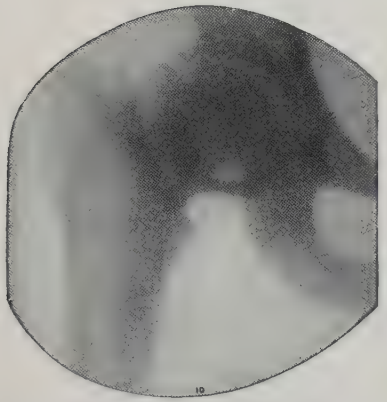


Fig. 1756.—Coxa vara following fracture of femoral neck.

Fig. 1757.—Spontaneous fracture near epiphysis of femur (rachitis).

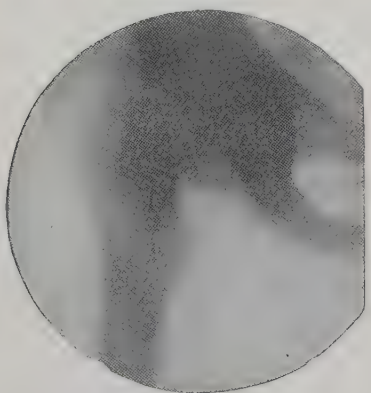


Fig. 1758.—Separation of epiphysis in coxa vara.

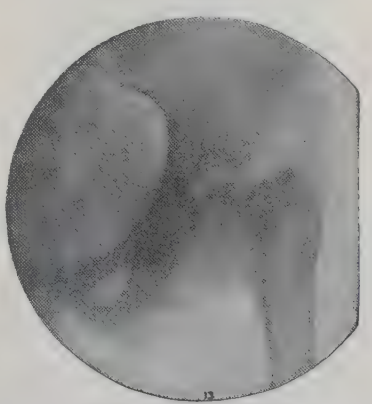


Fig. 1759.—Tuberculosis. Separation of epiphysis

Ultimate deformity is almost sure to occur. Very few fractures are recorded as happening after twenty years of age.

Treatment.—The treatment is protection from further fractures. Support to the injured bones. Cod-liver oil and phosphorus internally may be helpful. The increase of the calcium content of the blood in a case with a loss of calcium has not been accompanied by permanent improvement sufficiently frequently to lead me to place much confidence in its therapeutic value yet.

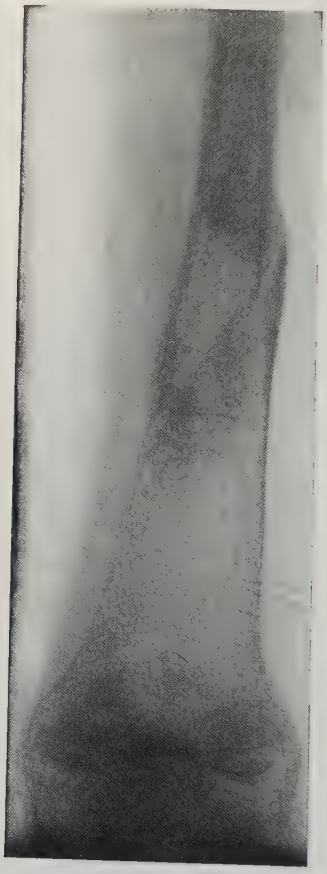


Fig. 1760.—Fragilitas ossium. A fracture which has occurred in the lower end of a femur, possibly the seat of fragilitas ossium.

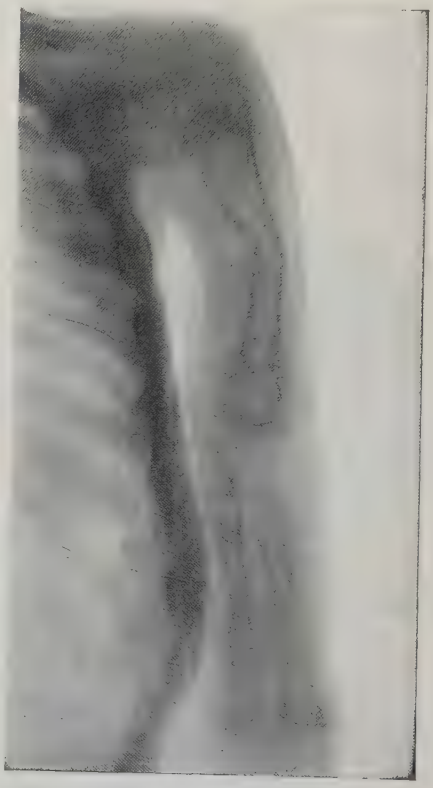


Fig. 1761.—Osteogenesis imperfecta (Dodd and Osgood).

Roentgen-ray Appearances.—The following summary made by Locke of the roentgenological appearances in these rare cases will prove helpful: A high degree of osteoporosis of entire skeleton, a mottled appearance, deformities of fractures, excess callous formation, epiphyseal cartilage is thin, cortex is thin and irregular, medulla irregular and enlarged, the spongiosa of epiphysis and diaphysis is very indistinct.

CHAPTER XXXVI

ANATOMICAL FACTS REGARDING THE EPIPHYSES

Our knowledge of injuries to the epiphyses has been obtained mainly through clinical and pathological observation. This knowledge is only approximately correct. With the assistance of the Roentgen ray a very great advance is being made in the accuracy of our knowledge of the epiphyses. Whereas there will, perhaps, always exist differences in the times of the appearance of the ossification centers and the times of union of the epiphyses, dependent upon individual peculiarities, the discrepancies in each observer's series of cases will grow less and less. In the very nature of the subject it will never be possible to establish a definite inelastic time limit within which each epiphysis will appear and unite with its corresponding diaphysis. It is important to be familiar with the average time in each instance.

The importance of an exact knowledge of the epiphyses to those having to do with injuries in the neighborhood of joints is undoubted. The diagnosis, prognosis, and treatment of joint injuries and injuries in the immediate vicinity of joints is far more satisfactory than ever before. The book by John Poland upon "Traumatic Separation of the Epiphyses," from which the following data are largely taken, marks an era in this branch of surgery. Only those facts that are considered especially important for practical everyday use are here mentioned:

THE DATE OF THE APPEARANCE OF OSSIFICATION IN THE CHIEF EPIPHYSES OF THE LONG BONES

At birth	Lower end of femur. Upper end of tibia.
At one year	Upper end of femur. Upper end of humerus.
At one and one-half years	Lower end of tibia. Lower end of humerus.
At two years	Lower end of radius. Lower end of fibula.
At three years	Great trochanter of femur. Great tuberosity of humerus.
At four years	Upper end of ulna. Upper end of fibula.
From five to six years	Upper end of radius.
At eight years	Lower end of ulna. Lesser trochanter of femur.
At ninth year	The olecranon process.

After a most exhaustive study of pathological and clinical material, both of his own and that of other observers, Poland concludes that the order of frequency of separation of the epiphyses is about as follows:

1. The upper epiphysis of the humerus.
2. The lower epiphysis of the femur.
3. The lower epiphysis of the radius.
4. The lower epiphysis of the humerus.
5. The lower epiphysis of the tibia.
6. The upper epiphysis of the tibia.

The roentgenogram is not a dependable source of information regarding injuries about the shoulder during the early years of life, for the epiphyses are largely cartilaginous.

Fig. 1762.—Epiphyses of the scapula at five years as shown by *x*-ray. (*x*-Ray, Dodd.)

Fig. 1763.—Epiphyses of scapula at fourteen years as shown by the *x*-ray. (*x*-Ray, Dodd.)

Greater force is necessary to cause a separation of an epiphysis than is required to cause a fracture of the same bone. In childhood severe trau-

matism to a joint will less frequently produce a luxation of that joint than a separation of the epiphysis. The periosteum remains attached to the epiphysis and is easily stripped from the diaphysis.

Fig. 1764.—Epiphysis of the upper end of humerus at five years. Note shape of epiphysis. (*x*-Ray, Dodd.)

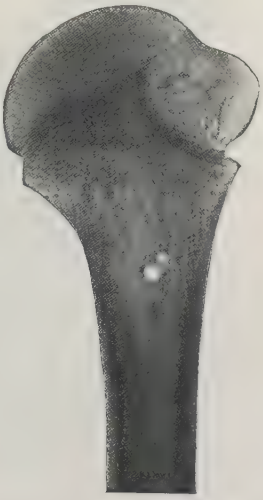


Fig. 1765.—Epiphysis of the upper end of the humerus at seven years. (*x*-Ray, Dodd.)

Pain is less in epiphyseal separation than in fractures. This is especially noticeable in separation of the upper epiphysis of the humerus. Pressure even very lightly over a fracture of the upper end of the humerus produces

Fig. 1766.—Upper end of humerus at eighteenth year. Epiphysis detached to show pyramidal end of diaphysis with its upward projecting apex (after Poland).

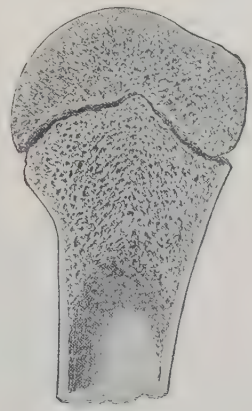


Fig. 1767.—Section of upper end of humerus at seventeenth year. Note cancellous structure and shape of diaphyseal end (after Poland).

pretty severe pain, whereas pressure over a separated upper humeral epiphysis does not evince much pain. This peculiarity is in evidence in injuries to the lower end of the radius as well.

The **upper epiphysis of the humerus** is composed of three separate centers of ossification: That for the head, appearing at two years; that for the

Fig. 1768.—Vertical section of shoulder-joint. The right half of the figure represents the posterior half; the left, the anterior half. *E*, Epiphyseal cartilage, between epiphysis (1) and diaphysis (2). 3, Glenoid cavity of scapula, showing its small size as compared with that of the head of the humerus. 4, Acromion process. Above it is seen the outer end of the clavicle. 5, Cavity of shoulder-joint, showing extent of joint surface and synovial membrane. 6, Brachial vessels and nerves (Eisendrath).

great tuberosity, appearing at three years; that for the lesser tuberosity, appearing at four years. These three centers coalesce to form the upper

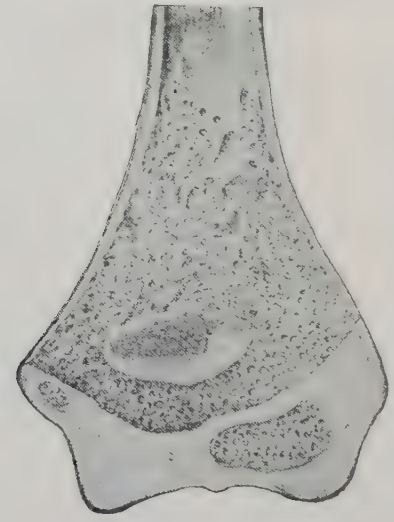


Fig. 1769.—Frontal section of lower end of humerus at the age of six and a half years. Anterior half of section. Centers of capitellum and internal epicondyle well developed. Actual size (after Poland).

epiphysis, and it unites, at from the twentieth to the twenty-fourth year, to the diaphysis of the humerus. The upper humeral epiphysis therefore

includes the two tuberosities, the whole of the head, and the anatomical neck. The cone-shaped end of the diaphysis appears more distinctly as age advances.

Fig. 1770.—Detachment of the epiphyses of the external epicondyle and of the capitellum. Age fifteen years (after Poland).

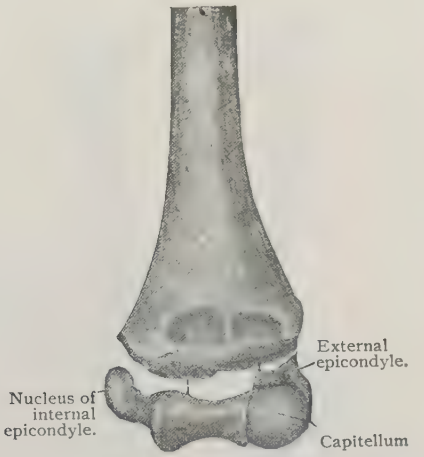


Fig. 1771.—Drawing of separated lower humeral epiphysis before puberty. The articular end is largely cartilage (after Poland).

In infancy the upper end of the diaphysis is almost flat across, consequently easily displaced and with difficulty held in place after reposition.

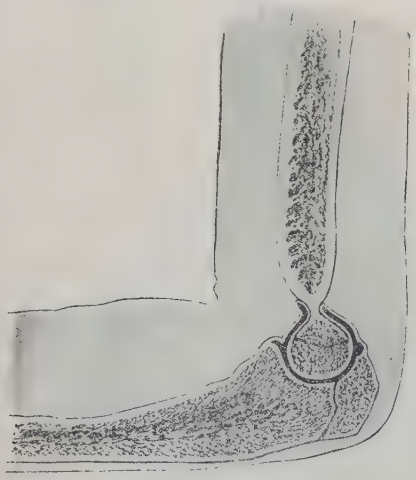


Fig. 1772.—Sagittal section of elbow-joint. Humero-ulnar articulation at fifteen and a half years. Note relation of the synovial membrane to the epiphyseal lines (after Poland).

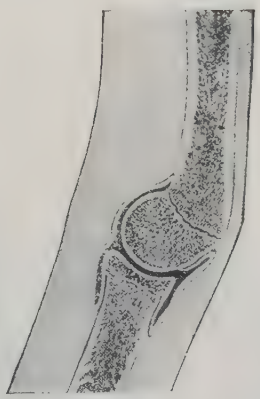


Fig. 1773.—Sagittal section through the outer portion of the elbow-joint. Note relation of the synovial membrane to the epiphyseal lines of the bones. Radiohumeral articulation at fifteen and a half years (after Poland).

Cohn believes, from his study of the epiphysis of the upper end of the humerus, that but one center exists for this epiphysis. Ossification begins soon after birth. The greater tuberosity is not a separate epiphysis, but a downward outgrowth from the head.

Separation of the upper humeral epiphysis will not necessarily, except in cases of very great violence, open the shoulder-joint, for the capsule is

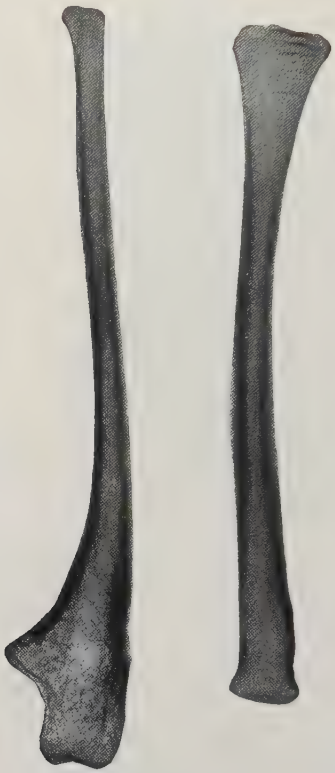


Fig. 1774.—Radius and ulnar epiphyses at five years. (*x*-Ray, Dodd.)

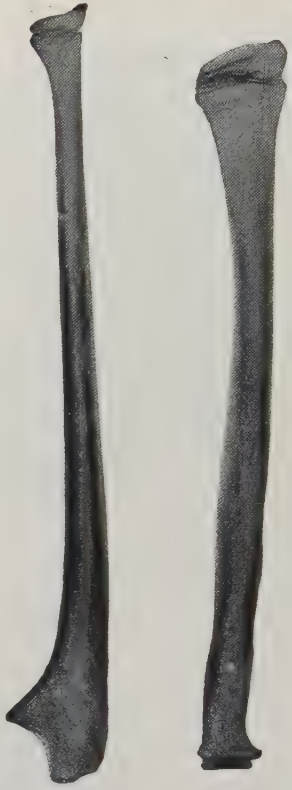


Fig. 1775.—Radius and ulnar epiphyses at seven years. (*x*-Ray, Dodd.)

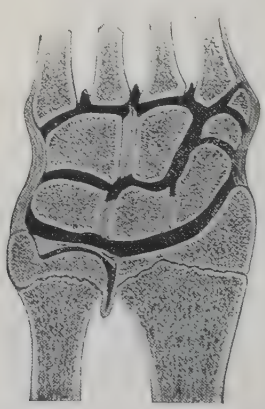


Fig. 1776.—Frontal section through the bones of the wrist and hand at eighteen years. Note the relations of the synovial membranes to the lines of the epiphyses (after Poland).

firmly attached to the epiphysis and the synovial membrane is loosely attached to the diaphysis. The epiphyseal line is intra-articular upon the inner side

Fig. 1777.—Epiphyseal lines as seen by the *x*-ray at nine years. (*x*-Ray, Dodd.)

Fig. 1778.—Epiphyses as seen by *x*-ray at fourteen years. (*x*-Ray, Dodd.)

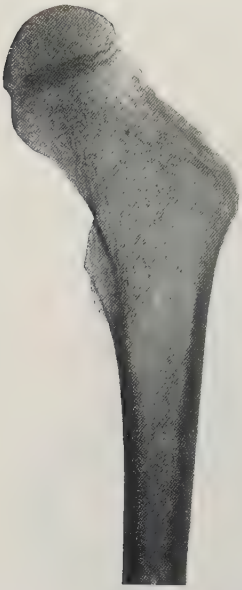


Fig. 1779.—Epiphyses of upper end of the femur at five years. (*x*-Ray, Dodd.)

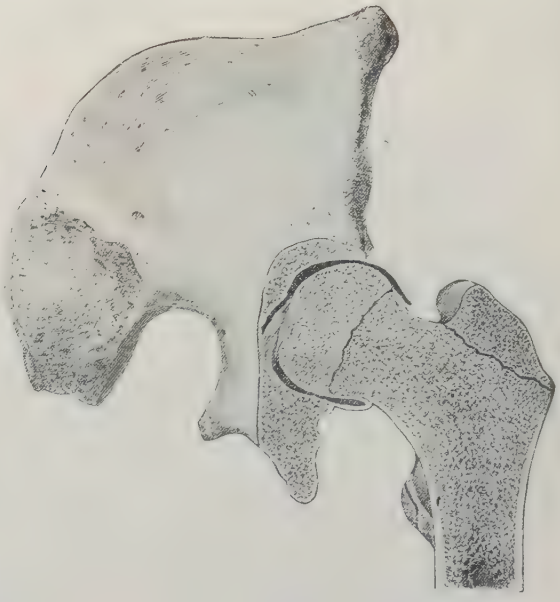


Fig. 1780.—Frontal section of left hip-joint in a boy seventeen and a half years old. Note relation of synovial membrane to the epiphyseal lines (after Poland).

Fig. 1781.—Epiphyses of the upper end of the femur at seven years. (*x*-Ray, Dodd.)

Fig. 1782.—Epiphyses of the upper end of the femur at fourteen years. (*x*-Ray, Dodd.)

only. In the adult the epiphyseal line marks the upper limit of the surgical neck. The growth in the length of the shaft of the humerus occurs from the upper humeral epiphysis. Conical stump cases following amputation of

Fig. 1783.—Lower epiphysis of femur. Upper epiphysis of tibia and fibula at five years. (*x*-Ray, Dodd and Osgood.)

Fig. 1784.—Lower epiphysis of the young adult femur. (*x*-Ray, Dodd.)

the upper arm illustrate how active the upper epiphysis is in the growth in length of the humerus.

Fig. 1785.—Lower epiphysis of the femur at fifteen years. (*x*-Ray, Dodd.)

Fig. 1786.—Upper epiphysis of tibia at five years. (*x*-Ray, Dodd.)

Fig. 1787.—Upper epiphysis of tibia at seven years. (*x*-Ray, Dodd.)

Fig. 1788.—Upper epiphysis of tibia at fourteen years. (*x*-Ray, Dodd.)

The Upper Epiphysis of the Femur.—There are three epiphyses for the upper end of the femur: one each for the head, the greater and the lesser trochanter.

The epiphysis for the head begins to ossify during the last half of the first year, for the greater trochanter during the fifth year, for the lesser trochanter during the ninth to the eleventh year. Complete union of all

Fig. 1789.—Lateral view of the upper epiphysis of the tibia. Note the bony connection of tibial tubercle center with upper tibial epiphysis.

Fig. 1790.—Epiphysis of the lower end of tibia at seven years. (*x*-Ray, Dodd.)

epiphyses with the shaft occurs between the fifteenth and sixteenth years (Cohn).

The **lower epiphysis of the femur,** the largest epiphysis in the body, appears before birth, attains a good size by two years, and unites to the

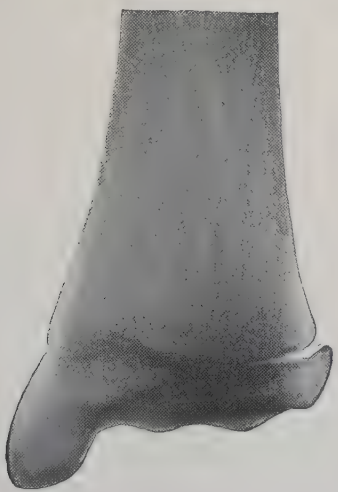


Fig. 1791.—Epiphysis of the lower end of the tibia at fourteen years. (*x*-Ray, Dodd.)

Fig. 1792.—Epiphyses of the normal lower end of tibia and fibula. Child aged five. (*x*-Ray, Dodd.)

diaphysis at from the twentieth to the twenty-third year. Cohn says from his observations that the nineteenth year sees this epiphysis united to the shaft of the femur.

The adductor tubercle is on the diaphysis marking the level of the line of the epiphysis upon the inner side of the femur. The two heads of the gastrocnemius muscle are attached to both the epiphysis and the diaphysis, but chiefly to the diaphysis. The plantaris is attached to the diaphysis. Both of these muscles, in a separation of the epiphysis, are stripped from the shaft with the periosteum, and act solely on the detached epiphysis, causing it to rotate upon its transverse axis. In separations without much displacement the knee-joint is not opened. The quadriceps bursa may escape injury.

The **lower epiphysis of the radius** appears during the first year, and unites to the shaft at from the twentieth to the twenty-first year.

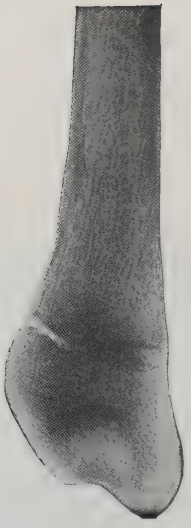


Fig. 1793.—Epiphysis (lower) of fibula at fourteen years. (*x*-Ray, Dodd.)

Fig. 1794.—Epiphyses of fibula at five years. (*x*-Ray, Dodd.)

The synovial membrane of the wrist-joint does not touch the epiphyseal line of the radius either anteriorly or posteriorly. It takes its origin from the lower articular margin of the epiphysis. The synovial membrane of the inferior radio-ulnar articulation extends above the epiphyseal lines of both the radius and ulna. It is loosely connected with the diaphysis of each bone. In epiphyseal separations laceration of the synovial pouch is possible, but is not absolutely inevitable.

The **lower epiphysis of the ulna** appears at the sixth or seventh year and ossifies about the twentieth to the twenty-first year.

The olecranon process of the ulna appears about the ninth year and unites with the shaft about the fourteenth year (Cohn).

The **lower epiphysis of the humerus** is formed from three separate centers of ossification—viz., the capitellum, which appears at three years; the trochlea, which appears at eleven years; the external epicondyle, which appears at thirteen years. These three centers coalesce at about the fifteenth year to form the lower humeral epiphysis. The epiphysis unites to the diaphysis at about the seventeenth year. The epiphysis for the internal epicondyle forms no part of the lower humeral epiphysis. It appears at about the fifth year, and joins the diaphysis at from the eighteenth to the twentieth year.

The synovial membrane at about the fifteenth year and afterward overlaps the epiphyseal line. The epiphyseal line is a little higher on the outer side than on the inner. It inclines obliquely downward and inward. The epiphysis is thinner internally than externally.

Cohn emphasizes the importance of a clear knowledge of the position of the capitellum. With the elbow at a right angle a lateral view of the elbow shows the capitellum occupying the sigmoid cavity.

In early life the capitellum does not fill the sigmoid cavity.

A plane passed through the middle of the long axis of the shaft of the humerus prior to the ninth year passes between the posterior border of the capitellum. After this year the same plane has two-thirds of the capitellum anterior to it.

The **epiphysis of the lower end of the tibia** appears about the second year, and unites to the diaphysis about the eighteenth or nineteenth year. Neither anteriorly nor posteriorly does the synovial membrane come in contact with the epiphyseal line, so that, unless great violence is exercised or the epiphysis is fractured, the ankle-joint is unopened in separation of this epiphysis.

The **epiphysis of the upper end of the tibia** appears at about the first year, and unites to the shaft at the twentieth or twenty-second year. The synovial membrane is quite a little distance from the line of the epiphysis. The epiphyseal line runs quite close to the superior tibiofibular articulation.

The **upper epiphysis of the fibula** appears about the fifth year, it is united to the diaphysis at the eighteenth year.

The **lower epiphysis of the fibula** appears at the beginning of the second year, and unites with the shaft at the eighteenth year.

The **acromion process of the scapula** presents an epiphysis that appears at from the fourteenth to the sixteenth year, and unites at from the twenty-second to the twenty-fifth year. The epiphysis includes the oval articular facet for the clavicle. The coracohumeral and acromioclavicular ligaments are attached to it. The epiphysis joins the acromion behind the acromioclavicular joint.

CHAPTER XXXVII

EPIPHYSEAL INJURIES

General considerations—Effect on bone growth—Effect on ossification.

Epiphyseal fractures are common injuries.[1] They may be overlooked and thought to be sprains. Careful stereoscopic Roentgen-ray examinations and records should be made following all injuries direct or indirect to the epiphyseal regions. An exact knowledge of the shape, location, time of the appearance of and time of union of the epiphyses as determined by anatomical and Roentgen-ray study is essential to every surgeon who would intelligently care for injuries to these important structures.

Epiphyseal injuries will include: (*a*) Separations of the epiphysis from the diaphysis, these will be complete or incomplete; (*b*) fracture lines extending into the epiphyseal line; (*c*) many cases in which the separation will be associated with a true fracture of the diaphysis near the epiphyseal line. Any epiphysis may be injured. The lower radial, humeral and femoral, and the upper humeral are perhaps the more commonly injured epiphyses.

The epiphyseal cartilage is stimulated to increased activity by trauma at a distance in the diaphysis of the same bone. Fracture of the shaft of a growing long bone is followed by an abnormal increase in the length of the bone as a rule.

When the epiphyseal cartilage itself is injured there is a retardation of growth from that cartilage. If complete replacement of the displaced epiphysis is made, shortening will be negligible. If a displaced epiphysis remains displaced there may result a considerable arrest of growth. The lack of shortening following many separations of the epiphysis is due to the fact that the fracture line does not pass exactly through the epiphyseal juncture, but through the newly formed bone adjacent to the cartilage.

It is a fact, as Haas has pointed out, that the fracture is usually oblique through the epiphyseal plate, damaging only a portion of the growing cells. Consequently, abnormalities of growth may occur without actual cessation of growth.

The cartilage itself is relatively resistant to injury, and ordinarily in epiphyseal separations the fracture line is found juxta-epiphyseal rather than in the cartilage itself. The importance of epiphyseal injuries depends upon the effect of the trauma on the growth and development of the affected bone. The active growth in length of the shaft of a long bone will take place rather more from one epiphysis than from another. Growth in length is not divided equally between the two terminal epiphyses. The arrangement of the nutrient arteries of the shafts of long bone apparently controls this factor.

[1] M. K. Smith, Annals of Surgery, February, 1924. E. D. Truesdell has studied epiphyseal injuries in the newborn (see Chapter xxxviii, p. 1070).

The nutrient arteries are directed toward the elbow-joint and away from the knee-joint. The epiphyses toward which the nutrient artery is directed unites to the diaphysis first. This is true with the single exception of the fibula. Consequently, the lower femoral epiphysis and the upper tibial epiphysis are the longest growing epiphyses, that is, the epiphysis adjacent to the knee-joint (Ollier). In the upper extremity the lower radial and upper humeral epiphyses, that is, the epiphysis at a distance from the elbow (Ollier), are the epiphyses which maintain the longest growth in length of the shafts of these respective bones. The effects of trauma then may be thought of as (1) a retarded growth from the injured cartilage, (2) a

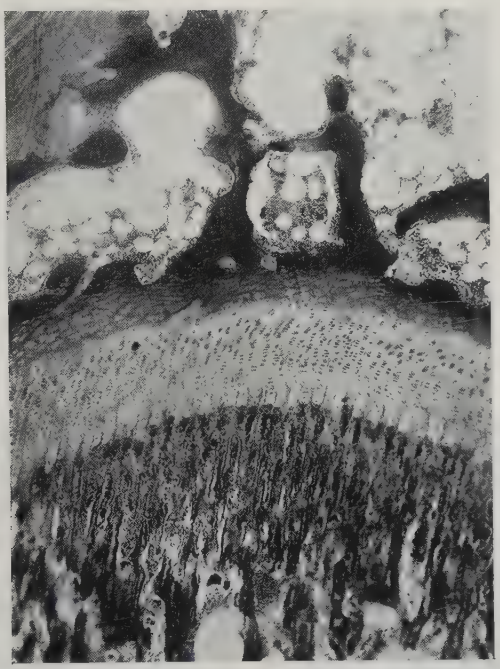


Fig. 1795.—Normal epiphyseal cartilage plate. Beginning from upper edge of plate we see in this section the epiphyseal ossifying cartilaginous layer with ossifying buds projecting into the epiphysis, the epiphyseal cartilage plate, the metaphysis (Haas, Amer. Jour. Orthopedic Surgery, August, 1917).

premature ossification, or (3) a normal growth in an abnormal position (M. K. Smith).

Having as a working principle that the most active and important elements necessary for longitudinal growth are located in the columns of cartilage of the epiphyseal cartilage plate, it is noticed that the nearer the injury comes to the cartilage columns the greater is the growth disturbance. Destruction of the direct blood-supply to the epiphyseal cartilage plate has a marked hindering of longitudinal growth. There is also found to be a relation between the degree of destruction of the cartilage columns and the loss of growth. These two factors along with the disturbance in the blood-supply form the more important principles governing bone growth. The injury to

the cartilage cells of the epiphyseal cartilage and the amount of destruction of the direct blood-supply—these two factors should determine and explain the clinical outcome following injury to the epiphyses (Haas). A direct

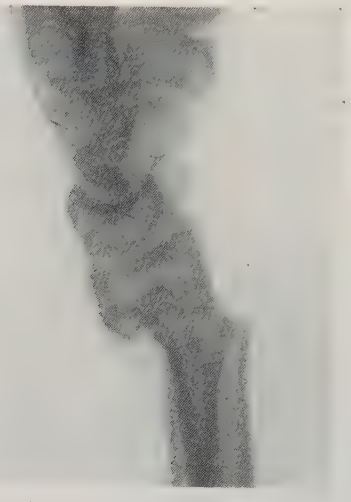


Fig. 1796.—J. C., age fifteen. Separation of the lower ulnar epiphysis with some diaphyseal fracture and fracture of the lower fourth of the radius (M. K. Smith).

Fig. 1797.—Same case as Fig. 1796, anteroposterior view (M. K. Smith).

Fig. 1798.—J. C., after nine months. Ossification at the injured ulna epiphysis is about completed. That of the radius on the uninjured side is apparently beginning. A roentgenogram taken seven months later showed both epiphyses on the injured side completely ossified. The process on the uninjured side was not complete, see Figs, 1796, 1797 (M. K. Smith).

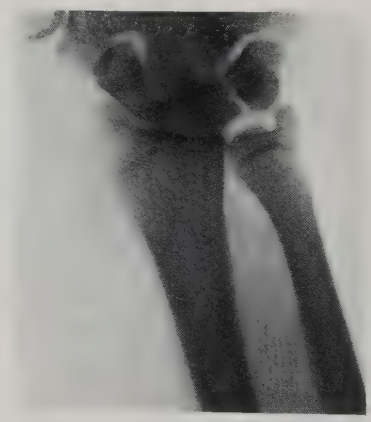


Fig. 1799.—J. C. Same case as Fig. 1798, uninjured wrist.

crushing injury to the epiphyseal cartilage plate always causes a loss of growth. The greater the injury to the cartilage cells and destruction of the blood-supply, the greater the loss of growth. It is known from experimental

data that excision of the epiphyseal cartilage plate means the cessation of length growth. In the case of a very severe crushing injury there may not

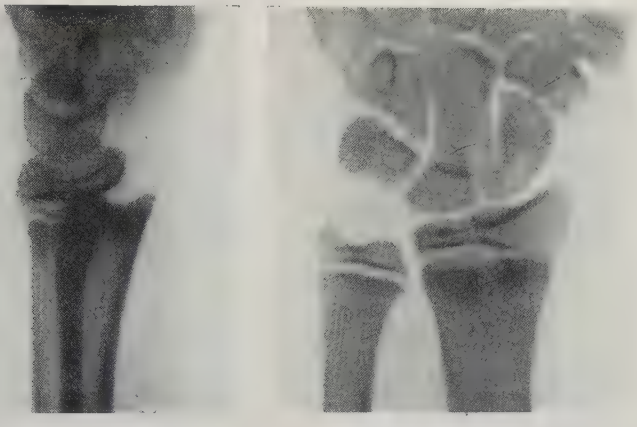


Fig. 1800.—D. G., age sixteen. Separation of the lower radial epiphysis with a vertical fracture through the epiphysis. Fracture of the ulnar styloid process (M. K. Smith).

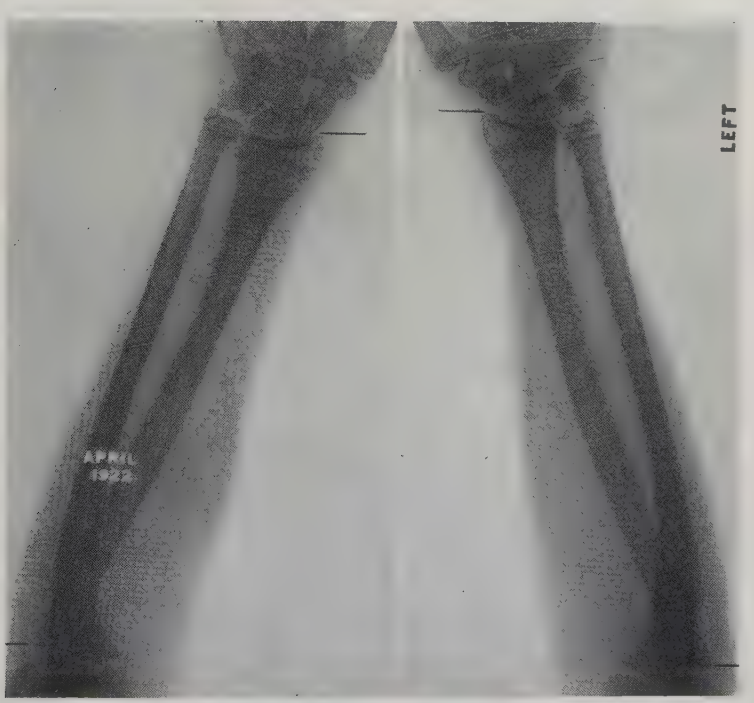


Fig. 1801.—D. G., one year later. There is retardation of growth of the injured radius. Note measurement of the two radii. Compare with Fig. 1800 (M. K. Smith).

be a complete cessation of growth, as some of the cells may retain their vitality and be capable of proliferating (Haas). The circulation enters the epiphyseal cartilage largely through the periosteal covering circumferentially.

This blood-supply may be greater than that entering from the nutrient artery. Destruction of parts of this blood-supply will have a definite influence on the development of the epiphyseal cartilage and its behavior after injury. Haas has pointed out a danger to be avoided in attempting forcibly to cor-

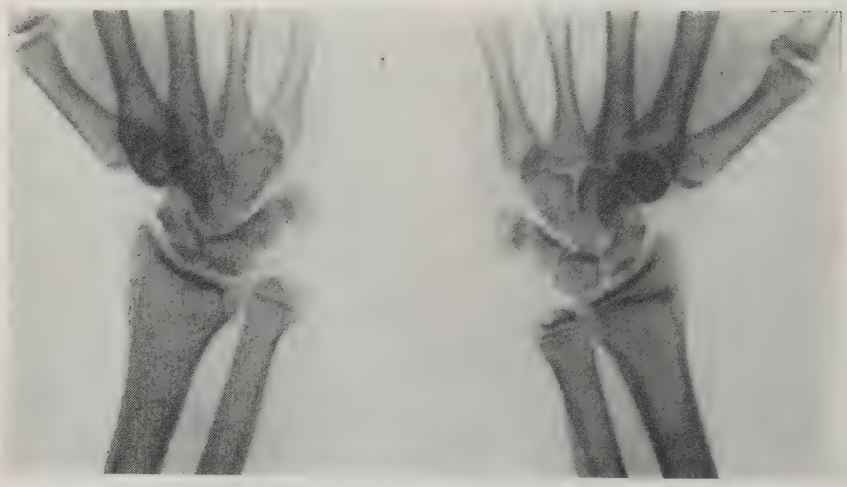


Fig. 1802.—D. G., two and a quarter years after the injury. Ossification of the injured radial epiphysis is largely completed. Definitely marked cessation of growth in the injured radius, more marked than is evident in Fig. 1801 (M. K. Smith).

rect a displaced epiphysis some ten days following the injury. Unless caution is taken the adjacent epiphyseal cartilage cell may be damaged permanently by such manipulation. In operating to reduce such displacements as little damage as possible should be done to the epiphyseal line cells. As much of

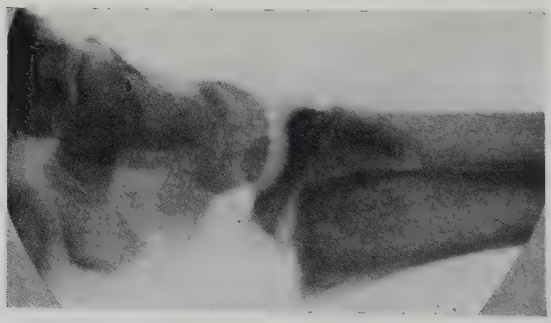


Fig. 1803.—Separation of the lower radial epiphysis backward (M. K. Smith).

the blood-supply of the epiphyseal cartilage should be preserved when operating as is possible.

The **prognosis** must be guarded following these injuries. Whether in any individual case the prognosis can be made with definiteness and precision will depend upon four factors:

1. The Roentgen-ray record of what has happened.
2. The extent of the injury.
3. The completeness of the reduction of the injury.
4. The age of the patient.

Fig. 1804.—Anteroposterior view. Pure separation of the lower radial epiphysis. J. W., age fifteen (M. K. Smith).

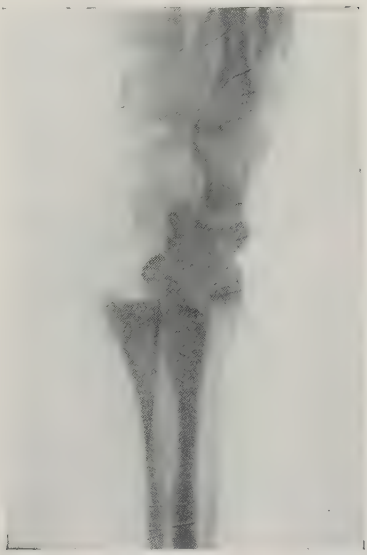


Fig. 1805.—Same as Fig. 1804. Lateral view.

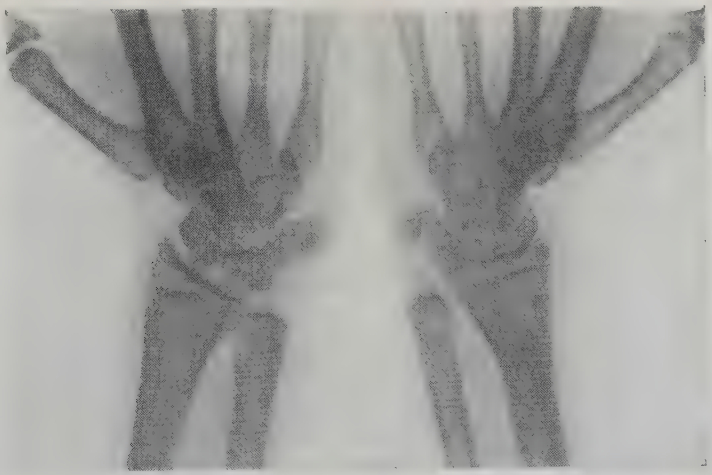


Fig. 1806.—J. W., six months later. Ossification of the radial epiphysis on the injured side. There is about ⅜ inch shortening (M. K. Smith).

There appears to be no prognostic difference in cases of pure separation and those associated with diaphyseal fracture. A very slight separation or starting of the epiphysis not requiring reduction may be followed by retardation of growth. A reduction should, of course, be attempted in all recent

cases, but without guarantee of a perfect result. When the reduction is necessarily incomplete there will often occur a remarkable compensation of the deformity by growth, so that in the course of a few months no evidence

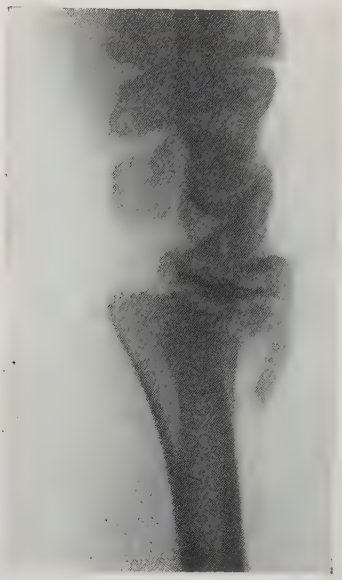


Fig. 1807.—T. B. Traumatic separation of the lower radial epiphysis carrying with it a thin shell of bone from the posterior surface of the diaphysis. The ulnar styloid was also broken. Boy of seventeen years (M. K. Smith.

Fig. 1808.—T. B. Compare Fig. 1807.

Fig. 1809.—T. B. Same case as Fig. 1810.

Fig. 1810.—T. B. One year after injury. Lower radial epiphysis completely ossified, while that of the ulna is largely so. Age eighteen years (M. K. Smith).

of the original injury remains. It appears from a study of the cases in M. K. Smith's series that there is more liability to permanent damage of the cartilage as the time for its function to cease approaches.

In a series of 38 epiphyseal line fractures studied by M. K. Smith from ten months to several years after the injury, 2, or about 5 per cent., showed an evident deformity due to retardation of growth. This series was largely of the upper extremity and includes 10 lower humeral cases, which, on account of the complicated nature of the epiphysis and slower growth at that end of the bone, are harder to evaluate.

Of 15 lower radial injuries, the commonest of the upper extremity epiphyseal fractures, 8 showed an effect varying from very slight (clinically negligible) shortening up to $\frac{3}{4}$ inch. Three showed premature ossification, 2 within a year and the third after two years. One of these presented a very evident deformity.

Retardation of growth is not necessarily associated with premature ossification.

It appears that the nearer growth is to completion, the greater is its liability to retardation. The 5 radial cases showing most effect averaged sixteen years as opposed to eleven years for the remainder.

It is not possible to predict the end-result from the extent of the original displacement as, on the one hand, some of these with severe injuries have shown no eventual shortening, while, on the other hand, among those who have well-marked retardation are patients whose original injury either needed no reduction or was satisfactorily reduced in the first place. The prognosis in epiphyseal line fractures should be guarded. Epiphyseal line fractures result in slight delay in growth in many instances and in a few cases result in sufficient retardation to be of clinical importance.

Upper Radial Epiphysis.—Montgomery records a separation of the upper radial epiphysis in a girl of eleven years. It is a very rare injury. Operation found the epiphysis free in the joint and at right angles to the radial shaft. It was replaced. Two years subsequently the injured epiphysis had firmly united to its shaft, whereas the uninjured epiphysis was not united. One year later, or three years after the injury and when the patient was fourteen years old, both epiphyses had united.

Careful measurement found that the injured radius was 1 cm. shorter than the uninjured radius.

The upper radial epiphysis appears at the sixth year, ossifies at the sixteenth year, and ordinarily unites at the seventeenth year.

In this case of Montgomery the slight amount of shortening did not cause any loss of function in the arm, which was normal in every way.

Epiphyseal injuries mentioned in the text of the book are as follows, and summarily arranged here will be readily accessible:

Separation of the Upper Humeral Epiphysis, p. 243.
Separation of the Lower Humeral Epiphysis, p. 312.
Separation of the Lower Radial Epiphysis, p. 380.
Separation of the Upper Femoral Epiphysis, p. 519.
Separation of the Lower Femoral Epiphysis, p. 605.
Separation of the Lower Tibial Epiphysis, p. 711.

CHAPTER XXXVIII

BIRTH FRACTURES[1]

General remarks—Fracture of the clavicle—Fracture of the skull—Fracture of the humerus—Fracture of the femur—Dislocation of the epiphyses.

General Remarks.—In the experience of Truesdell birth fractures have always been *complete fractures*. The idea is quite general and not without ample support in the books that incomplete or greenstick fractures are common in the newborn. Numerous birth fractures thought to be greenstick fractures have been found on *x*-ray examination to be not only complete, but to have wide separation of the fragments. The bones at birth are quite brittle. It is common for a bystander to hear a humerus or femur snap during manipulations carried on within the uterus or cervix. Such an audible snap may be heard in a dislocation of the lower humeral epiphysis, the operator thinking that he had broken the arm.

Truesdell has met no so-called "spontaneous" or "intra-uterine" fractures among cases of birth fracture.

Fracture of the Clavicle.—This occurs usually during difficult breech extraction, sometimes preceded by version. The situation of the fracture is near the center of the bone, the fracture is nearly transverse, the displacement is similar to adult clavicular fracture displacement. There are rarely symptoms to attract immediate attention. The arm may hang unused. The first sign of fracture may be the appearance of a callus at the seat of the fracture. Treatment for two weeks by a swathe or cravat sling or Velpeau gauze bandage applied with the usual precaution against chafing of the skin will prove satisfactory. A fracture of both clavicles may be treated by a double figure-of-8 about the shoulders, holding the shoulders back. Union of fracture of the clavicle always occurs. Greenstick fracture of the clavicle has not been seen.

Fracture of the Skull.—The softness and pliability of the skull bones and the opportunity for adjusting themselves through the wide open sutures makes the bones of the vault relatively free from fracture. Symptoms of brain injury of a most serious sort are commonly observed with perfect integrity of the overlying bones. On the contrary, a fracture of the vaul of the skull may be present without apparent evidence of injury to the underlying brain. The injury from undue forceps pressure rarely if ever causes a fracture of the skull. A traumatic periostitis of the parietal bone is recorded from forceps pressure. A most unusual Roentgen-ray record of such a case is seen in Fig. 1814 (Truesdell).

[1] The material in this chapter is taken by permission from the unique and valuable Monograph, Birth Fractures and Epiphyseal Dislocations, by Edward D. Truesdell, M. D., New York (Paul Hoeber Co.).

Fissure fracture of the cranial bones occurs. It may be due to compression of the head in the pelvic inlet during difficult breech delivery; to

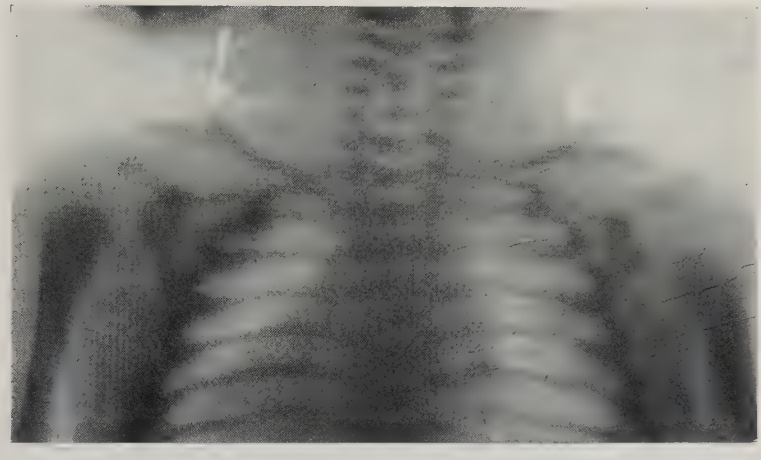


Fig. 1811.—Birth fracture of both clavicles. A not uncommon variety of birth injury usually produced during difficult breech extraction with arms extended above the head. The cross splint and the figure-of-8 bandage hold such fractures rather well (Truesdell).

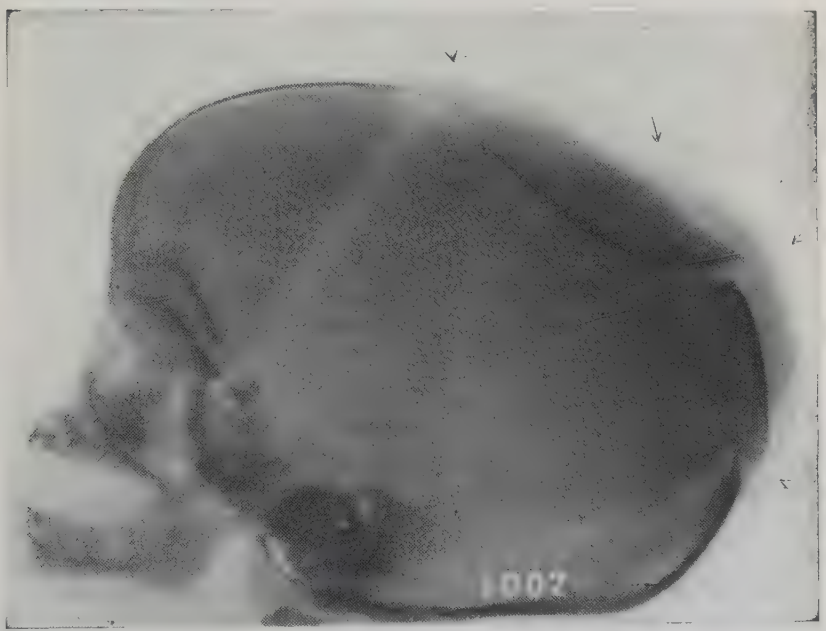


Fig. 1812.—Case II. Fissure fracture of the parietal bone, produced by intense uterine contractions accompanying the expulsion of a large child presenting by the face. A large hematoma of the scalp surmounted the fracture; there was no evidence of intracranial injury (Truesdell).

an injury during forceps delivery; to a fall on a tiled floor some 3 feet, or to a face presentation in a large child associated with vigorous uterine contractions. Symptoms: A subperiosteal hematoma formed by the accumula-

tion of blood under the pericranium in the immediate region of the fracture. It is, of course, present at birth, increasing slightly in size during the first twenty-four hours. It is to be distinguished from the ordinary cephalhematoma by the fact that the latter does not appear for several days after birth. The fracture hematoma is irregular in outline, feels soft and watery. The cephalhematoma raises the pericranium from margin to margin of the bone involved and is tense and elastic upon palpation.

Treatment: Depression of the vault of the skull should be immediately elevated whether symptoms of pressure upon the brain are present or not. Even though no symptoms are present at birth or shortly after, there is no certainty that important symptoms may not develop months or years after

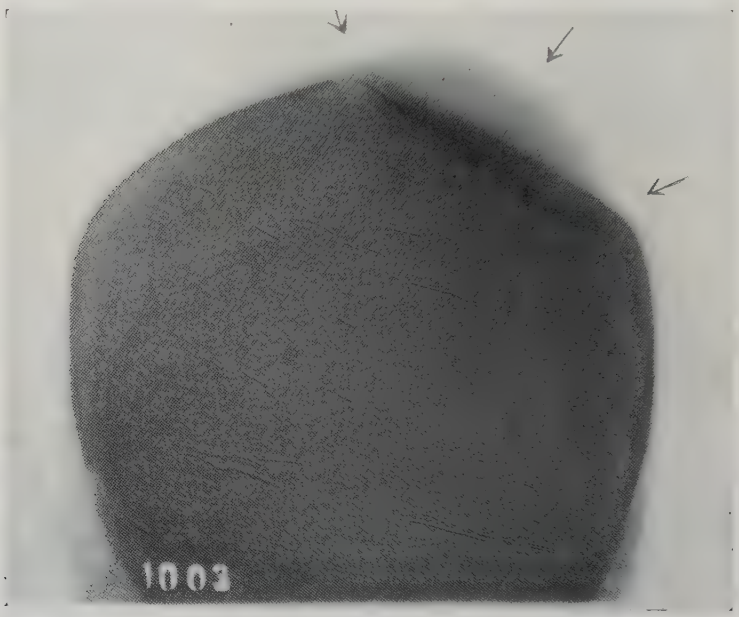


Fig. 1813.—Case II. The anteroposterior view showed a depression of the fractured portion of the parietal bone, with the overlying hematoma. Because of the hematoma no immediate attempt was made to elevate the fragment, which had spontaneously returned to approximately its normal position by the end of the first week (Truesdell).

depression of the skull bones. Moreover, it has not yet been proved by Roentgen ray that there is depression fracture of the inner table associated with certain of these depressions of the skull without symptoms.

Kosmak has devised an instrument made by the Kny-Scheerer Company, New York, for elevation of the depression. He has reported four depression fracture cases successfully elevated. Three were of the frontal bone with pressure symptoms—completely relieved by operation; one was a parietal depression.

Davis in a case of a depression of the right frontal bone without symptoms through an incision elevated the depression by a periosteal elevator passed beneath the bone.

Kerr has employed successfully and advocated gentle firm compression of the skull from before backward, that is, anteroposteriorly in those cases having a spoon-shaped depression high up in the skull. If a long time has elapsed since the occurrence of the deformity it may be impossible to reduce it without an operative procedure. No spoon-shaped depression of the newborn skull should be permitted to remain permanently unreduced.

Tweedy has suggested the introduction of a volsellum forceps blade beneath the depressed bone and thus effecting elevation.

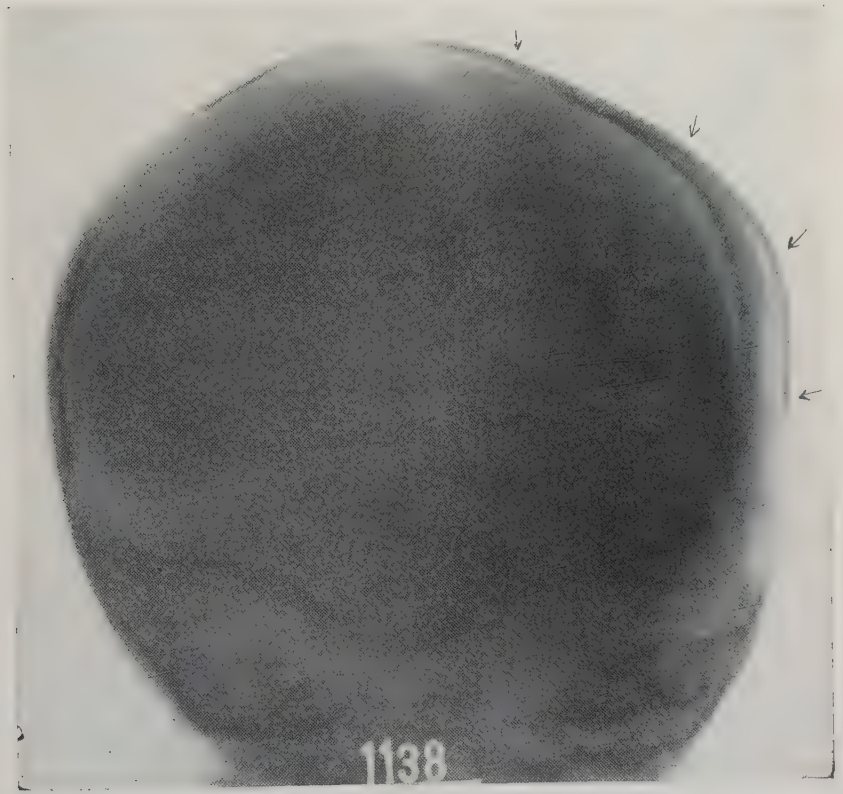


Fig. 1814.—Case II. At the eleventh month the infant was found to be normal in every respect. There was slight asymmetry of the skull. The roentgenogram showed slight flattening of the calvarium in the region of the birth fracture, with some thickening of the parietal bone below (Truesdell).

Fracture of the Humerus.—The humerus is the bone most frequently broken during delivery. A fracture of the humerus in the newborn is rarely overlooked. These fractures are the result of manipulations to aid or effect delivery. Breech extraction following version, breech extraction in cases of breech presentation, and difficulty with the arms at the pelvic outlet in vertex presentations, all contributed to these injuries to the humerus. All fractures have been near the center of the shaft of the humerus below the deltoid insertion. Ordinarily, the line of fracture is transverse. There are recorded no fractures of the upper or lower ends of the humerus. Although the fracture

may be subperiosteal and without much displacement commonly, extensive laceration of the periosteum exists with considerable displacement of the fragments. There is a sharp outward angulation of the fragments, with or without anteroposterior displacement. The angulation is often very marked. Overriding or rotation of the fragments, while common, is probably not a matter of great importance.

Symptoms.—The arm hangs helpless at the side. Motion exists at the center of the humeral shaft. Crepitus and swelling of the arm are commonly noted. Ecchymosis is rarely observed.

Treatment.—The treatment consists in the elimination of the angulation by manipulation and the fixation of the arm at the side of the chest wall with a

Fig. 1815.—Indentation of the parietal bone without fracture in a child five and a half months old, showing that such depressions may occur without fracture. Depression was elevated by trephining the bone at the bottom of the depression and raising with a blunt hook (Luckett, Annals of Surgery, Truesdell).

simple adhesive-plaster swathe, the forearm in a position of comfortable flexion, this covered by a Veapeau bandage of gauze, and this, in turn, secured by numerous strips of narrow adhesive plaster. All splints of rigid material are both impractical as well as unnecessary at this time of life and for this condition.

Uncorrected deformities have been found to disappear spontaneously in cases of birth fracture of the humerus during the first two years, angulations becoming curves of the shaft of the bone, and these gradually disappearing until a straight shaft, indistinguishable from the uninjured bone of the opposite side, finally results. Up to the second week following fracture it has been possible to correct remaining deformity by careful manipulation. Even though nature can be relied on to compensate for deficiencies of treat-

ment of these cases, the fracture requires as careful and efficient initial treatment as do any fractures.

Birth-fractures of the shaft of the humerus have been uniformly associated with some degree of paralysis of the musculospiral nerve, a traumatic paralysis, producing "drop-wrist." This has never been observed to be permanent.

Birth-fracture of the humerus is a cause of "dangling-arm." The difficulty in delivery that has explained the fracture has often been the cause of

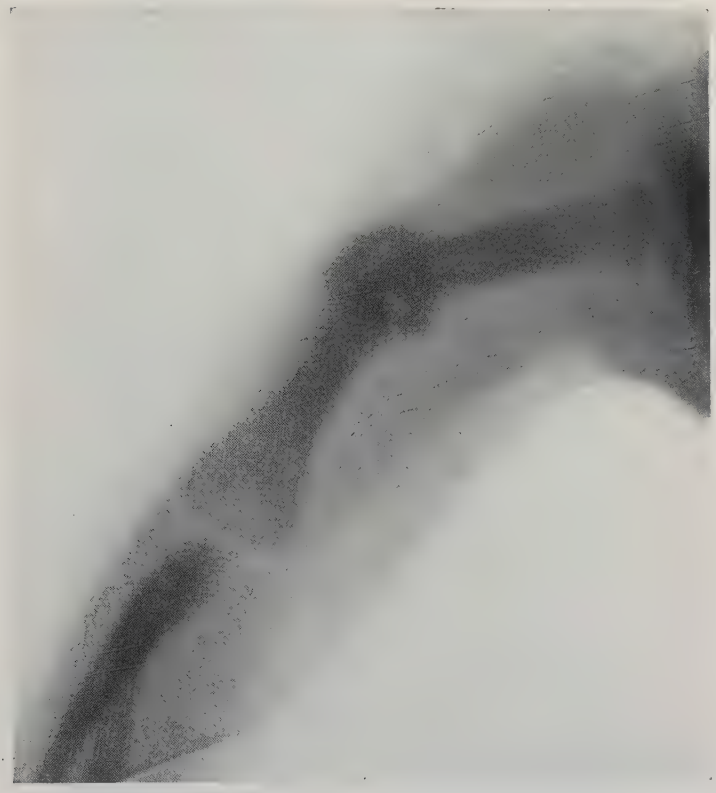


Fig. 1816.—Case I. Birth fracture of the humerus, referred for Roentgen examination after firm union had occurred. Note the callous mass at seat of fracture with the fragments fixed in external angulation No attempt made at this time to correct the deformity. Kept under observation (Truesdell).

injury to the brachial plexus in the neck, producing an Erb birth paralysis. This is readily overlooked in the presence of the fracture with drop-wrist. Erb's birth paralysis has occurred in, roughly, 8 to 10 per cent. of the cases and is of far more importance than either the fracture or the injury to the musculospiral nerve. Until it is possible to be assured that this injury has not occurred, along with a fracture, the prognosis in regard to the eventual outcome should be guarded. The result so far as the fracture alone is concerned is almost certain to be entirely satisfactory, while with Erb's paralysis, particularly in its more severe forms, there may result some per-

manent impairment in the function of the arm. It is interesting to note that the residual deformities following fracture of the humerus do not tend to disappear in the presence of Erb's paralysis. They tend to persist if not corrected originally.

The arm should be immobilized for three weeks and during that time the condition of the skin should be watched, particularly in the axilla and the fold of the elbow. The finger-nails should be kept short.

Fig. 1817.—Case I. At the eighteenth month even the curvature had been largely eliminated, the medullary canal re-established, while the development of the bone had been unimpaired (Truesdell).

The *x*-ray is a great help in the treatment of these cases. It need not be employed until the tenth day, when the final correction of the position can be made, the fragments placed in the position it is expected them to unite within the next few days. The Roentgen ray will show callus between the eighth and twelfth day.

Fracture of the Femur.—This is a relatively infrequent fracture, resulting in considerable deformity, often improperly treated; therefore demanding careful consideration. Fracture occurs in the shaft of the bone at about the

middle rather than at either end. It is usually a complete fracture. These fractures are incidental to the operative force of breech extractions in breech deliveries following version, or in extracting a leg through the uterine incision in cesarean section. There is considerable displacement of the fragments. The upper fragment is displaced forward. There is a marked external angulation. The displacement is associated with laceration of the periosteum, often extensive. Sometimes the displacement is further complicated by penetra-

Fig. 1818.—Case I. Little disparity between humeri at end of third year. The bones were of the same length, the functions of both arms were normal. There remains an insignificant outward curvature of the shaft of the humerus (Truesdell).

tion of the thigh muscles by the ends of the sharp fragments. Unless the anterior angulation is corrected there will be a permanent (for some years) deformity. The tendency to overcome or compensate this femoral fracture deformity of the unreduced or improperly treated fracture is less than in the case of the fractured humerus. Recognition and adequate treatment of fracture of the shaft of the femur is, therefore, very important.

Treatment.—It is apparent according to Truesdell's experience and the experience of those handling this fracture that:

Fig. 1819.—Case IV. Untreated birth fracture of the humerus of two weeks' standing. Note new bone about the seat of fracture. There was fairly firm union; the displacement was very extreme (Truesdell).

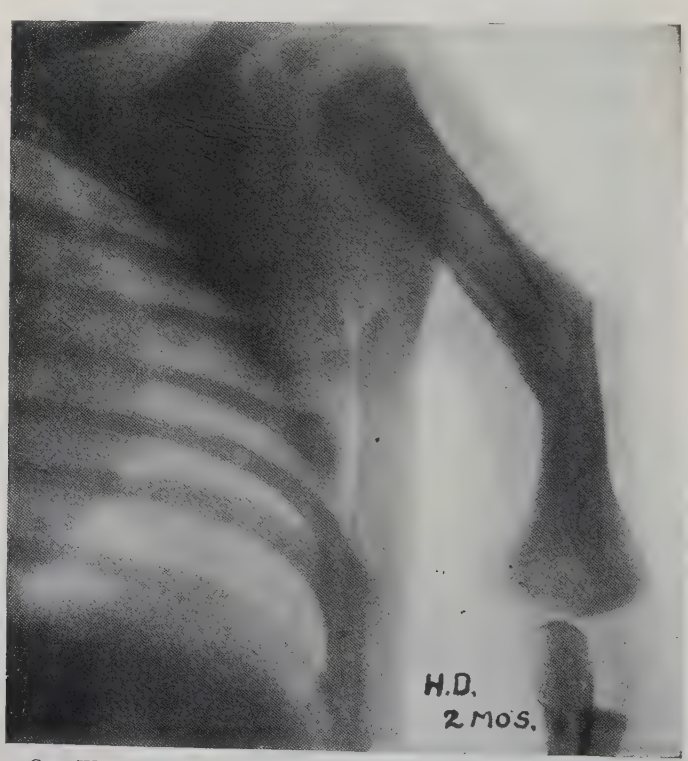


Fig. 1820.—Case IV. Following the roentgenogram at second week an attempt was made to correct the extreme deformity. This roentgenogram was taken after eight weeks. Note still an outward curvature of humerus. Note evidences of firm union (Truesdell).

1. It is very important to prevent angulation of the fragments. These persisting angulations do not tend to disappear. Truesdell has followed cases of this fracture seven and eight years which still show residual deformity (anterior curvature) due to the uncorrected angulation.

2. The common deformity is the anterior and external angulation.

3. The overriding of the fragments to a moderate degree is the least important factor. If this overriding can be corrected, it is wise to correct it.

Fig. 1821.—Case IV. Nine months after the injury the bone was found well on its way to a restoration to normal. There was decrease in the outward curvature, the medullary canal had been re-formed (Truesdell).

It is, as compared to a similar deformity in the adult, relatively unimportant.

4. Treatment of the fracture in the straight or extended position of the limb is absolutely unwarrantable and contraindicated (Truesdell). The normal attitude of the newborn child is one of general or acute flexion. All

efforts to overcome this flexed position are vigorously resisted by the infant. These facts alone suggest the best position for treatment of the fractured femur.

The treatment ordinarily used in extension by the inexperienced has failed to prevent deformity. The flexed position is required. The Van Arsdale splint (see Figs. 1838–1840) meets this indication. But even the Van Arsdale splint is not adequate to correct the overriding of fragments. The Truesdell box traction splint meets all the requirements. It is a bit more complicated, less easily made, but more effective.

Fig. 1822.—Case VI. Roentgenogram of birth fracture of the humerus on the eighth day showing the second and less common type of deformity in the transverse plane, lateral displacement of the lower fragment.

Boorstein[1] has recently recorded satisfactory results from the treatment of birth fracture of the humerus and femur with the aid of small, properly adjusted Thomas splints with complete and with open ring.

As a *summary*, it may be stated that treatment by the straight extended position is contraindicated (Truesdell). The use of the flexed position maintained by a Van Arsdale splint or equivalent, or by a Truesdell splint, is best. Martin W. Ware, New York, has used satisfactorily a pasteboard triangle and plaster-of-Paris spica apparatus with success (see Fig. 1837). The principle is similar to that of the Van Arsdale splint. Charles H. Robins, Richmond, Virginia, has used successfully the modified Cabot wire splint (see Fig. 1841). I record these splints, as they may prove suggestive.

[1] Jour. Amer. Med. Assoc., December 12, 1925, vol. 85, pp. 1866–1869.

The Van Arsdale Splint (see Figs. 1838–1840).—This splint may be easily made by cutting from thin sheet metal (tin, preferably aluminum) as outlined in Fig. 1838, bent at a right angle at *A*, and secured in this position by bringing the prolongations (*B*) together. The wings (*C*) are then bent over to form the sides of the splint applied to the injured thigh and the side of the infant's body. The splint is covered with Canton flannel and applied with roller bandages reinforced with strips of adhesive plaster. Bending the splint at *A* to make less than a right angle will permit of considerable flexion of the

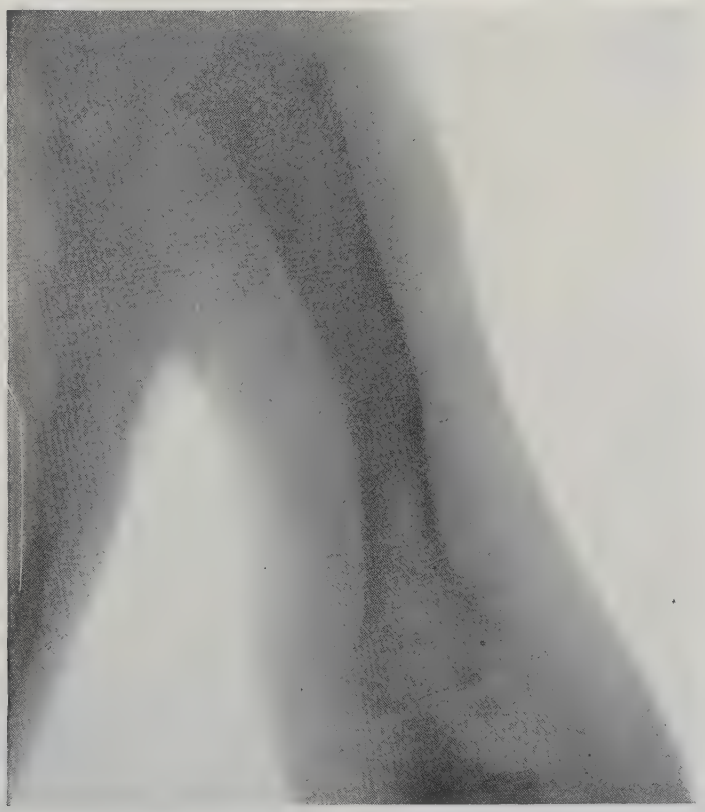


Fig. 1823.—Case VI. At fourteen months the injured humerus was found to have nearly straightened out. Measurements and functions of the arms were equal (Truesdell).

thigh on the body which will correspond to the extreme degree of flexion of the upper femoral fragment. Thus a better alignment of fragments will be possible. The splint may be adapted to different degrees of deformity.

The Truesdell Box Splint (see Figs. 1853, 1854).—This splint combines several features of importance:

1. Comfortable position for infant.
2. Ease in maintaining cleanliness.
3. Flexion of thigh on the body.
4. Moderate continuous traction.

5. Facilitating carrying infant about.
6. Control of rotation of lower fragment through manipulation of foot-piece.
7. Countertraction through weight of body on inclined bed.
8. The ability to abduct thigh and leg.

The *box splint of Truesdell* is very satisfactory. The infant is placed on its back in a cushioned box into which it fits snugly. A broad band of adhesive plaster or webbing is passed across the abdomen and around the box,

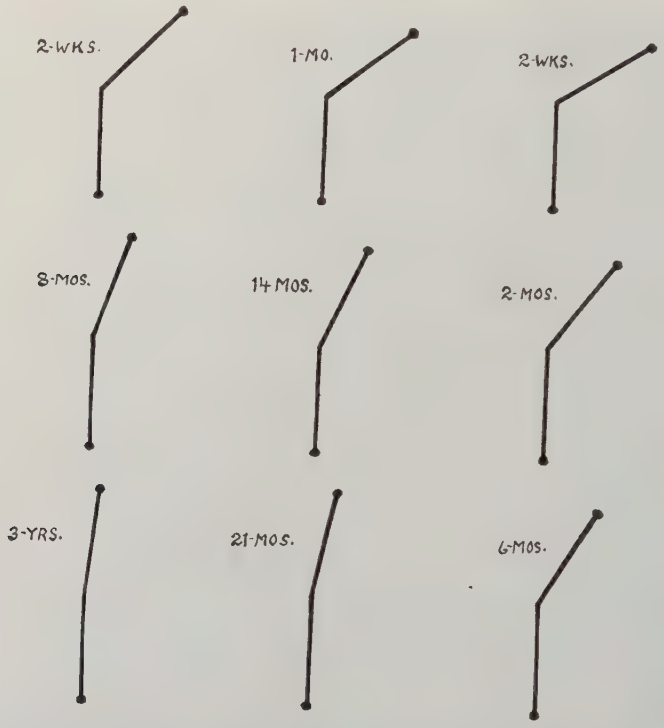


Fig. 1824.—Fracture of the shaft of the humerus. Diagram made with the object of showing the degree of initial angular deformity existing, displacement of the fragments, and the subsequent progress toward elimination of the deformity by nature. The lines going to form the angles represent the long axes of the fragments of the fractured bones, converging toward the point of fracture. An initial deformity of 45 degrees or more may eventually result in a perfectly straight bone at the third year. This diagram is made from tracings of roentgenograms of Cases I, III, and IV. The first vertical column from Case I, the second from Case III, the third from Case IV.

to afford countertraction; two strips of adhesive plaster are applied to the leg as high as possible on the thigh to the ankle and held in place by a roller bandage. The lower ends of these plaster strips are cut and folded upon themselves to form narrow straps of some strength, suitable for passing through the holes of the foot-piece. These are drawn up snugly and secured so that the sole of the foot is brought flat against the surface of the foot-piece, thus controlling the tendency to drop-foot. The foot-piece itself is attached to a length of cord or stout tape. This is passed over the pulley or the top of the upright, and tied to a large elastic band caught over the hook at its

base, which is intended to afford the necessary amount of traction. Two webbing bands and buckles, which are tightened, are necessary to bring the fragments into the desired position, and are passed about the injured thigh

Fig. 1825.—Fracture of humerus. A swathe dressing holding the broken arm to the chest wall and the elbow flexed is found satisfactory for fracture of humeral shaft. The skin is cared for and properly protected from irritation by the dusting-powder (Truesdell).

Fig. 1826.—Fracture of humerus. Over the adhesive plaster swathe is placed a Velpeau bandage. Roentgen rays should be taken through this dressing. The arm is immobilized for about three weeks (Truesdell).

and the upright, one above and one below the point of fracture. The box splint provides flexion of the thigh to a little less than a right angle, which should bring the lower fragment of the femur into such a position as to meet

the upper without angulation, thus correcting the undesirable anterior deformity. The box splint provides abduction of the leg, preventing outward angulation. It provides traction as required to overcome shortening. It provides the broad base of the foot-piece resting upon the surface of the upright, and prevents rotation of the leg and thus the occurrence of rotary deformity of the fragments.

This splint dressing will require frequent changing. The skin condition should be carefully watched and appropriately treated. The splint will need adjustment from time to time. The tendency to a persisting anterior

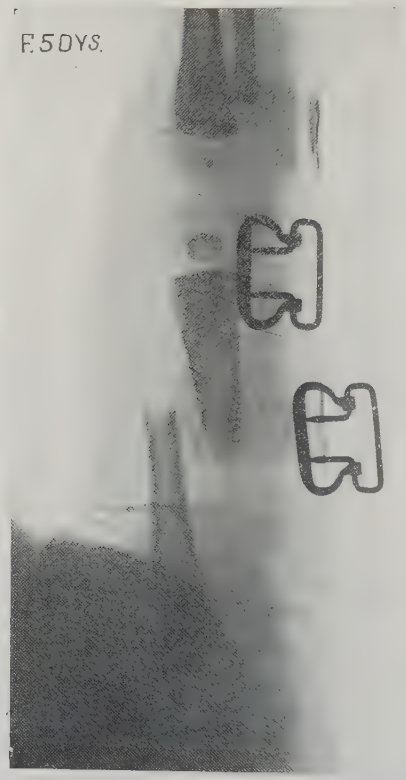


Fig. 1827.—Case VIII. Birth fracture of the femur treated from the day of delivery in the Truesdell box splint (see Fig. 1853). Note this *x*-ray, taken on the fifth day, showed parallel fragments separated and overriding (Truesdell).

displacement must be met. Very great care in the delivery of breech presentations and the performance of breech extraction and delivery of the child from a cesarean incision will tend to avoid the occurrence of fracture of the femur.

The possibility of post-traumatic acceleration of growth of this bone in children should be kept in mind in passing judgment upon the efficiency of a particular method of treatment, and particularly when some radical procedure is contemplated for the correction of overriding.

The site of the fracture is irrelevant in its relationship to the stimulation

of bone growth. Overgrowth has been found to be as great in fractures of the upper, middle, and lower thirds of the femoral shaft. No compensatory activity in growth takes place. The inequality persists after ten years.

Dislocation of the Cartilaginous Epiphyses.[1]—When force is brought to bear on the ends of the long bones a dislocation of an epiphysis will occur rather than a true joint dislocation or fracture. The epiphyses of the humerus and of the femur are most liable to injury at birth. The *diagnosis* can be made with assurance at the time of the accident and can be later verified by Roentgen-ray record. The birth dislocations of the cartilaginous epiph-

Fig. 1828.—Case VIII. At six weeks the separated fragments, while parallel, were bridged by compact bone. Union was firm and the splint had been removed (Truesdell).

yses studied by Truesdell to date have been produced by operative delivery, either a breech extraction following version or the same procedure employed to terminate a protracted labor in cases of breech presentation. Something in the limb may be felt to give way during manipulation of the child. After delivery one of the baby's extremities has been found to hang limp and to dangle. Fracture is eliminated, for fracture occurs at the center of the shaft. False motion at an epiphysis can be detected or strongly suspected and may be accompanied by a grating or soft crepitus. *After the first day* a large firm

[1] Truesdell's study of this subject represents pioneer work.

swelling, often tender, exists in the deep structures of the extremity injured, most marked in the region of the damaged epiphysis and shading off along one-half or two-thirds the length of the shaft of the bone involved. *Two weeks later* this swelling has diminished in size, increased in density to that of bone. Gradually the infant will resume the function of the limb. The swelling may exist for two or three months or more, gradually disappearing. *By the second week* the Roentgen ray will have given conclusive evidence of the injury. New bone will be seen to have formed beneath the stripped up periosteum. The *treatment* will consist in an attempt to replace the dis-

Fig. 1829.—Case VIII. Ten months after fracture there was marked increase in the length of the bone, while a moderate degree of anterior curvature had resulted. Evidence of the backward displacement of the lower fragment had disappeared. The outcome could be considered fair, but not as good as if an opportunity for more careful treatment had existed (Truesdell).

placed epiphysis. Unfortunately, it is impossible to tell the success or failure of treatment until after the opportunity for a desired readjustment has passed. The upper epiphysis of the femur and the humerus remain in their articulations and the shaft is forced away from the head. Operative replacement is practically never indicated. Fractures of the shaft of the femur are six times as common as dislocation of the femoral epiphyses (Truesdell).

Even when the displacement has been considerable and the replacement imperfect, the outcome has been good. No better evidence of the restorative

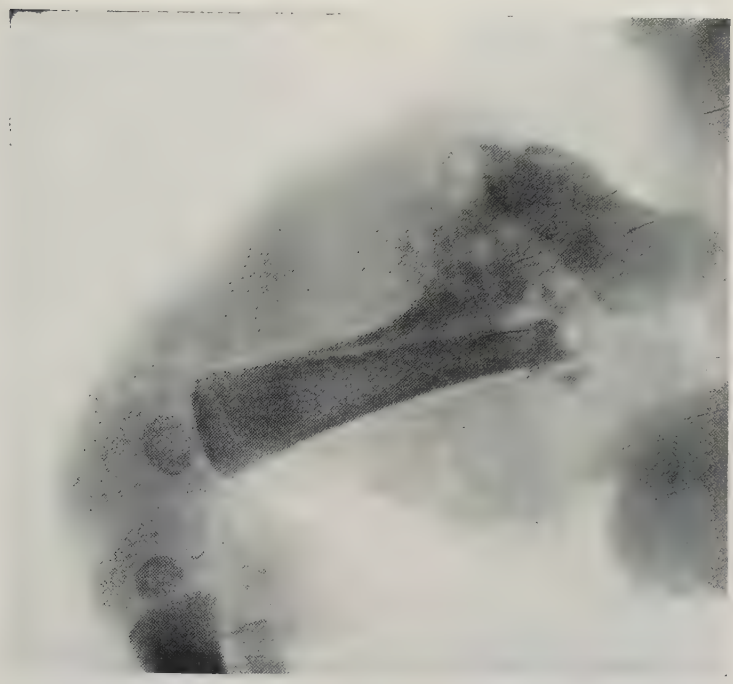


Fig. 1830.—Birth fracture of the femur following breech delivery. This *x*-ray nineteen days following injury. Note flexion of the short upper fragment, overriding is extreme. The anterior angular deformity Note dense excessive callus. No remedial measures possible except open reduction (Truesdell).

Fig. 1831.—R. E., born July 22, 1917. Fracture of shaft of femur at birth. Now fifteen months old. Note angulation at seat of fracture very marked (Truesdell).

and corrective ability of nature during the early years of life can be obtained.

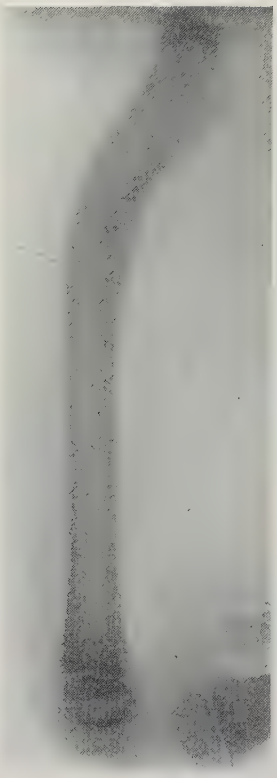


Fig. 1832.—R. E. Same case as Fig. 1831. Child now three and a half years old. Note angulation is less than at five months (see Fig. 1833).

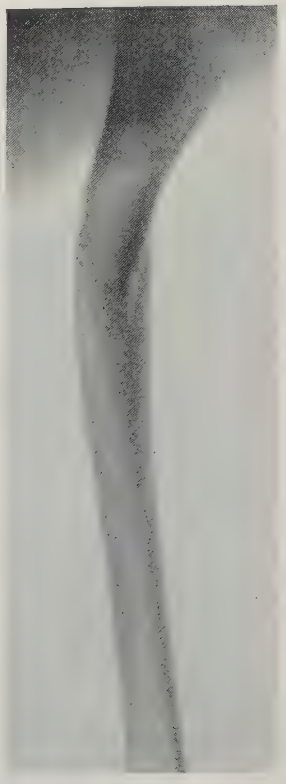


Fig. 1833.—R. E. Same case as Figs. 1831–1833. Child now seven and three-quarters years old, Note great diminution in angulation. Note also that the seat of fracture has moved away from the hip through growth in length of the shaft (Truesdell).

Fig. 1834.—Case III. Fracture of femoral shaft at tenth week. Note angulation. Fragments separated, overriding; much callus. Appearances in case unrecognized and untreated or inadequately treated (Truesdell).

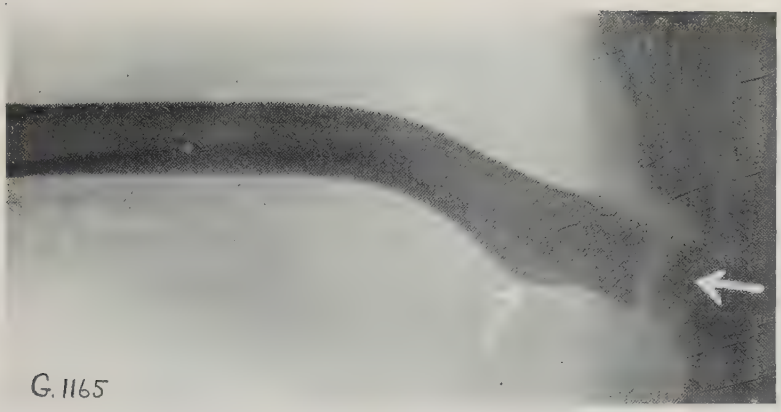


Fig. 1835.—Case III. Three years after. View made with the thigh flexed at a right angle with the body and abducted to show more clearly the type and degree of deformity characteristic of cases of birth fracture of the femur where measures to correct the all-important flexion of the proximal fragment have failed or been omitted in early treatment. Note that the seat of fracture has moved upward as the bone grows from the lower end (Truesdell).

Fig. 1836.—Ware's apparatus for treatment of fracture of both femora (Ware, Annals of Surgery, August, 1905).

Fig. 1837.—Ware's combined pasteboard triangle and plaster-of-Paris spica apparatus for fracture of the femur in infancy (Ware, Annals of Surgery, August, 1905).

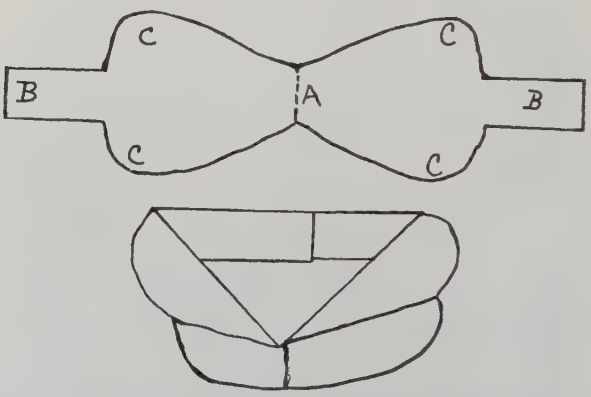


Fig. 1838.—The van Arsdale splint pattern. To be cut from thin sheet metal, preferably aluminum, bent to a right angle at *A*, and secured by bringing the prolongations, *B*, together. The wings, *C*, are bent over so as to form the sides of the splint applied to the injured thigh and same side of infant's body. When the fracture is in upper third of femur by bending the splint at an acute angle accurate apposition of the fragments is possible.

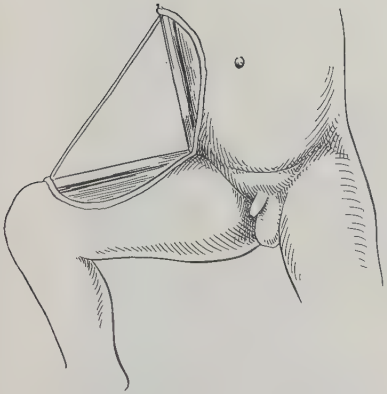


Fig. 1839.—The van Arsdale splint diagrammatically represented in position.

Fig. 1840.—The van Arsdale splint. Fracture of left femoral shaft. Dressing completed. Note the felt padding of splint (Truesdell).

Fig. 1841.—Birth fracture of shaft of the femur. A bent Cabot wire splint fitted to an infant to maintain flexion and abduction of thigh and leg (Robins, Southern Surg. and Gyn. Trans., 1907).

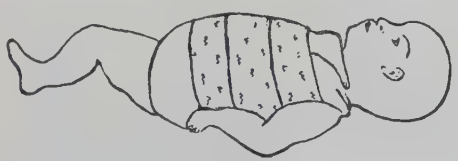


Fig. 1842.—Fracture of the femoral shaft in the newborn. Note the lower extremity forcibly and completely flexed upon the body (thigh extended), foot resting on clavicle, bandage holding part still. Comfortable and natural position for newborn baby.

Fig. 1843.—Case I. Birth dislocation of the upper humeral epiphysis. The arm hangs useless at the side, there is swelling about the shoulder due to extravasation within and without the shoulder-joint. Difficult breech extraction—arms extended above the head (Truesdell).

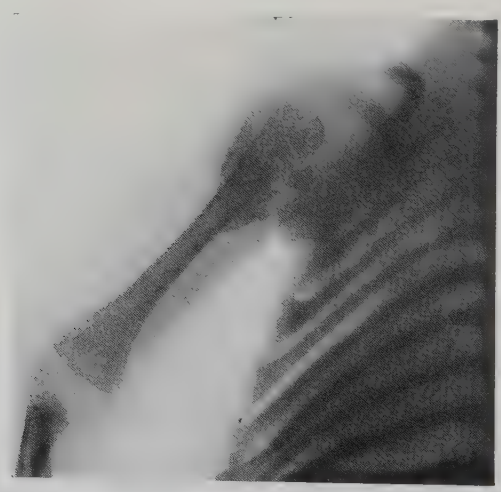


Fig. 1844.—Baby H. Birth dislocation of the upper humeral epiphysis twenty-two days after injury. Note the formation of new bone under stripped periosteum (Truesdell).

Fig. 1845.—Case I. Birth dislocation of the upper humeral epiphysis. Difficulty with arms in breech extraction following a version. Something was felt to have snapped. There was no fracture of the humerus. There was distinct abnormal mobility between the shaft and head of the humerus. There was no voluntary use of arm. It fell limp at side. *x*-Ray examination the day of birth eliminated fracture, but not separation of an epiphysis (Truesdell).

Fig. 1846.—Case I. Lateral view on the twelfth day. Lateral aspect of humerus. Above and in front of the shaft is seen a rounded mass of new bone deposited beneath the periosteum at the point of rupture at the epiphyseal line. On the posterior surface of the shaft is seen a slender wedge of new bone, with base above shading off for half the length of the shaft. This has been formed from the periosteal bridge that passes from the displaced epiphysis to the shaft of the bone from which it has been detached. This *x*-ray indicates that the shaft is displaced forward in front of the head of the humerus which is in the glenoid cavity (Truesdell).

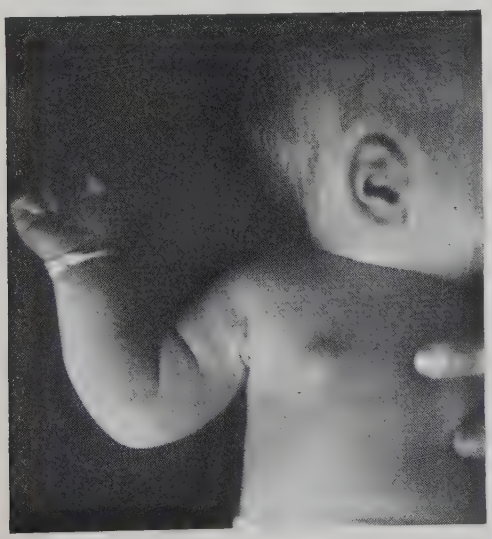


Fig. 1847.—Birth injury. Dislocation of the lower right humeral epiphysis. Note the swelling of elbow. (Compare with Fig. 1848, Baby K., and with Fig. 1843) (Truesdell).

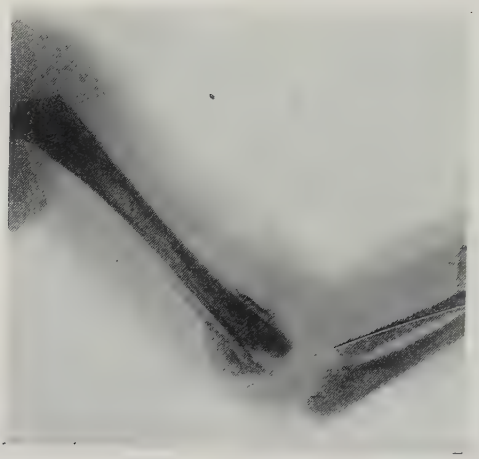


Fig. 1848.—Baby K. Birth dislocation of the lower humeral epiphysis twenty days after injury (Truesdell).

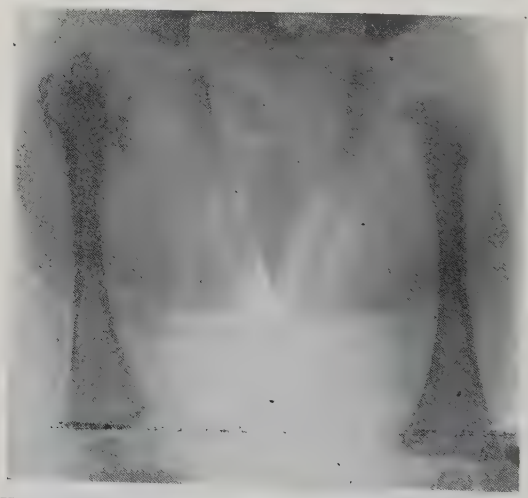


Fig. 1849.—Case II. Birth dislocation of the upper femoral epiphysis. A difficult breech extraction. A large firm swelling in upper part of the thigh. Appearance by *x*-ray four weeks after injury. Swelling of thigh less marked. Note new formed bone from ruptured periosteum at the separated epiphyseal line and subperiosteal new bone from stripped up periosteum the whole length of the shaft (Truesdell).

Fig. 1850.—Case II. *x*-Ray after three months; same case as Fig. 1849. A rudimentary femoral neck has been formed extending toward the femoral head in the acetabular cavity. The displacement outward of the original shaft of the femur is seen. Note great length of neck of femur in injured as compared with uninjured side (Truesdell).

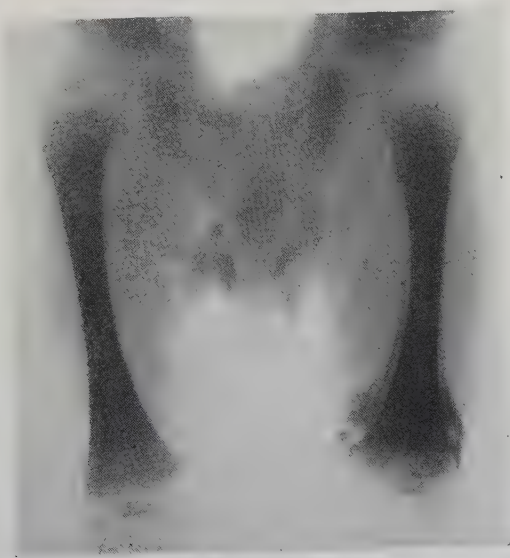


Fig. 1851.—Case III. Birth dislocation of the lower femoral epiphysis. Immediate *x*-ray showed no fracture of the shaft of the femur. *x*-Ray on sixteenth day. The characteristic new bone production is noted. The epiphysis itself is in position now (Truesdell).

Fig. 1852.—A diagram made from the tracing of roentgenograms to represent the position, approximate size and shape of the swelling observed in cases of birth dislocation of the femoral epiphyses. The dotted lines indicate the swelling found on the second day and after, in the lower and upper thigh, in lower and upper epiphyseal birth dislocation (Truesdell).

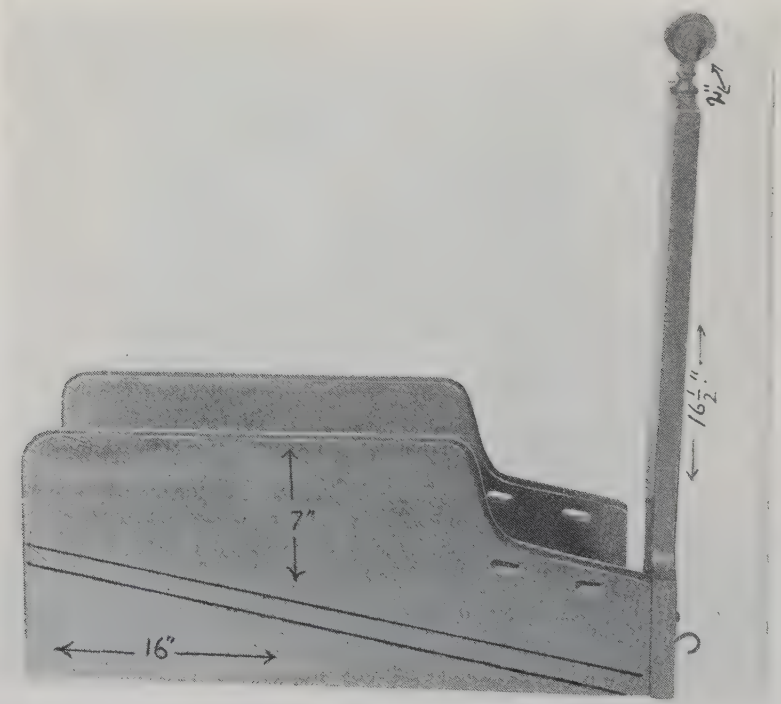


Fig. 1853.—Fracture box for treatment of birth fractures of femur, showing measurements of sides in inches and inclination of bottom to help prevent infant from pushing itself back and away from upright. Also showing holes in sides for straps of belt to hold infant down and give countertraction.

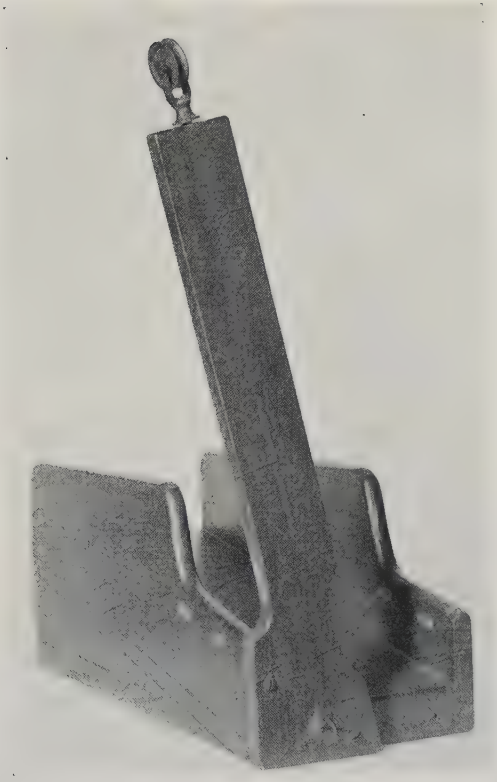


Fig. 1854.—End view showing attachment of upright, which can be used upon either side of end according to which leg is injured, hook for rubber band and pulley at top to carry tape to foot-piece. Note that inner edge of upright is cut away to expose perineum. Diaper can or need not be employed as desired. I have sometimes used two straps with buckles about thigh, above and below fracture, if needed.

A recent paper by Pierson calls attention to the frequent occurrence of cervical dislocations in difficult breech extractions.

Spinal cord injuries apparently due to obstetrical manipulations are altogether too common (Cruthers). A careful study of the *x*-ray records in this chapter will prove most instructive.

CHAPTER XXXIX

GUNSHOT FRACTURES OF BONE

The civil surgeon rarely has opportunity to study the effect upon bone of bullet wounds. He may see in his practice a few gunshot fractures. His experience is necessarily limited. The facts contained in this brief chapter are taken from the experience of such military surgeons as Kocher, Treves, Nancrede, Makins, Senn, Borden, La Garde, and others who have during the past few years studied scientifically this important class of wounds.

In the construction of the modern military rifle several important changes have been made. The bore of the rifle has been reduced. The caliber of the bullet has been lessened. The velocity of the bullet at the muzzle has been increased. The trajectory is more flat. The revolution of the bullet upon its long axis is increased.

As a general result of these various changes the modern military rifle has a great range and great accuracy. The effect of the modern bullet upon bone is described as concisely as is possible in the following paragraphs.

The amount of the damage done to bone is dependent upon several factors: The greater the velocity of the bullet when the bone is struck, the greater will be the destruction of the bone. The muzzle velocity of the modern bullet is ordinarily about 2000 feet a second. The less the velocity, the less will be the destructive effects. The velocity may be just sufficient to break the bone and not to carry the bullet through the limb. The severity of the injury, therefore, decreases in proportion to the distance which intervenes between the rifle and the object struck. The trained military surgeon may read the range in the character of the damage done. The more pointed bullet secures for itself greater penetration and perforation. The bullet acts like a steel wedge driven with great velocity through the soft and hard parts. The primary collision area is small. The only indisputable evidence of a low velocity is the lodgment of an undeformed bullet. The resistance offered by the tissues is lessened and the resulting wounds are neat. Important parts are seemingly miraculously avoided by the bullet. The revolution of the bullet on its long axis facilitates a neat wound of entrance through the skin. The Mauser bullet revolves on its own axis once in $8\frac{11}{16}$ inches, or about half of a full revolution in the perforation of a limb. The amount of destruction suffered by any part of a bone depends primarily upon the amount of resistance which it opposes to a bullet. There is more resistance offered by the cortex found in the shaft than by the spongy tissue of the ends of the long bones. When the hard shaft or cortical bone is hit, the force of the bullet is expended in breaking this dense and resistant bone into minute pieces.

The explosive effect of a bullet is dependent upon the velocity remaining to be expended upon the small particles of bone broken off by the initial

impact. The carrying of these particles of bone forward into and through the tissues causes the laceration and tearing so characteristic of the so-called

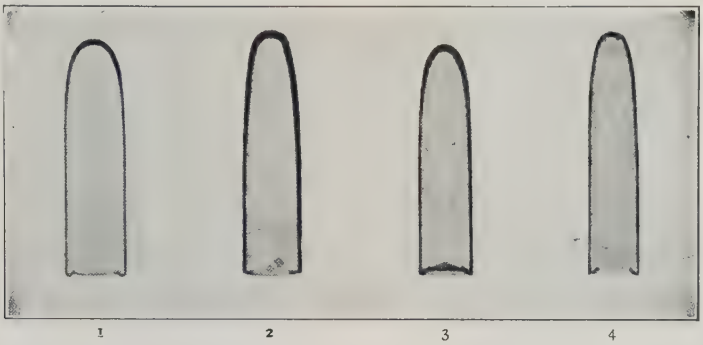


Fig. 1855.—Sections of bullets to show relative shape and thickness of mantles: 1, Geudes: regular dome-shaped tip; mild steel mantle; thickness at tip, 0.8 mm.; at sides of body, 0.3 mm.; 2, Lee-Metford: ogival tip; cupro-nickel mantle; thickness at tip, 0.8 mm.; gradual decrease at sides to 0.4 mm.; 3, Mauser: pointed dome tip; steel mantle plated with copper alloy; thickness at tip, 0.8 mm.; gradual decrease at sides to 0.4 mm.; 4, Krag-Jörgensen: ogival tip as in Lee-Metford; steel mantle plated with cupro-nickel; thickness at tip, 0.6 mm.; gradual decrease at sides to 0.4 mm. Note the more gradual thinning in the Lee-Metford (from Makins' "Surgical Experiences," etc.).

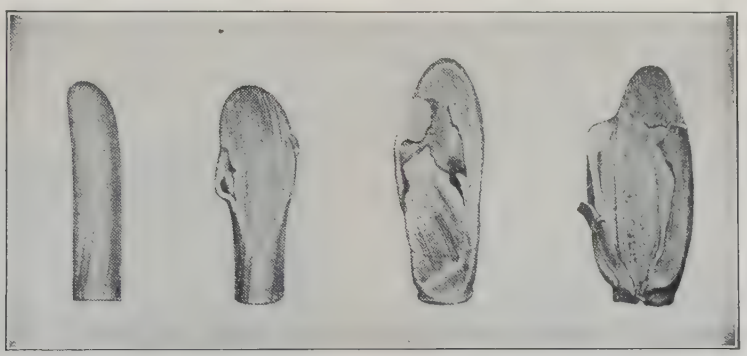


Fig. 1856.—Four common types of lateral Mauser ricochet bullets (from Makins' "Surgical Experiences," etc.).

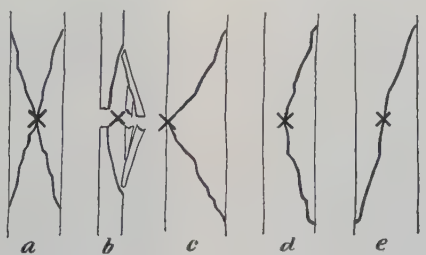


Fig. 1857.—Five types of fracture: *a*, Primary lines of stellate fracture; *b*, development of the same lines by a bullet traveling at a low degree of velocity; the two left-hand limbs seen in (*a*) absent; in their places is seen a transverse line; *c*, typical complete wedge; *d*, incomplete wedge; *e*, oblique single line (from Makins' "Surgical Experiences," etc.).

explosive effect of a bullet. The detached bony particles become really secondary missiles.

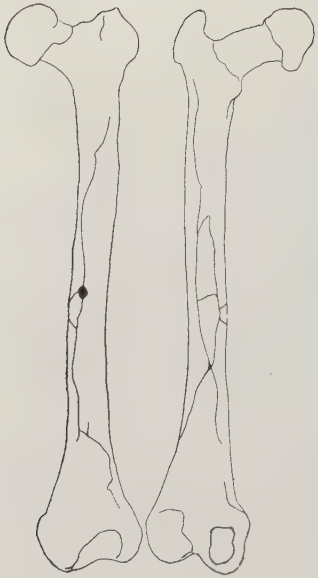


Fig. 1858.—Diagrammatic view of a type of fracture of the femur, the bullet entering on the anterior surface of the bone causing extensive longitudinal fissuring of the shaft. The articular ends of the same have not been involved in the fracture (after Kocher).

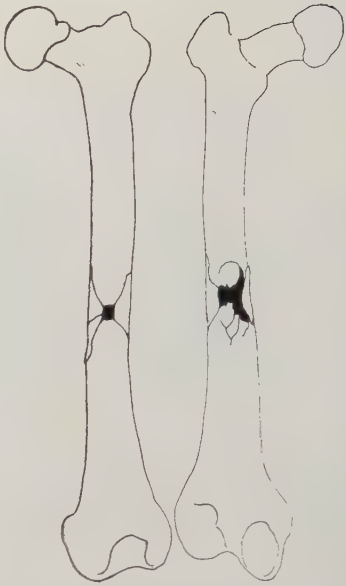


Fig. 1859.—Diagram of a type of fracture. The entrance wound clean cut, the exit wound lacerated, and larger than the wound of entrance (after Kocher).

Fig. 1860.—Typical stellate fracture of the ulna (from Spencer, "Gunshot Wounds").

Fig. 1861.—Stellate fracture of the fibula (from Spencer, "Gunshot Wounds").

Kocher has classified the parts of the long bones injured as the diaphysis, the epiphysis, and the part between the two, the metaphysis. The cortical

Fig. 1862.—Comminution of the radius (Stevenson).

Fig. 1863.—Fracture of the radius near its lower end, with many fragments of the broken-up bullet, and a second fracture higher up (from Spencer, "Gunshot Wounds").

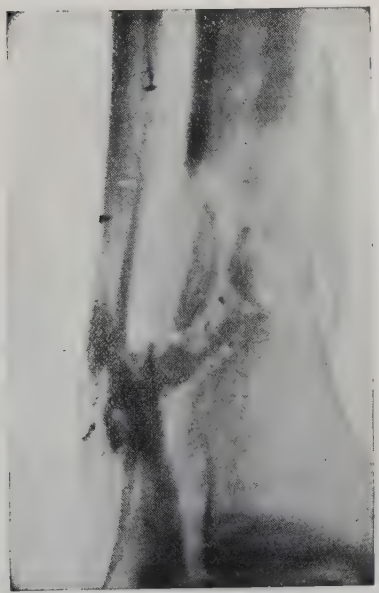


Fig. 1864.—Severely comminuted fracture of the tibia and fibula (from Spencer, "Gunshot Wounds").

Fig. 1865.—Stellate fracture of the second metacarpal (from Spencer, "Gunshot Wounds").

layer of the metaphysis is thin and the spongy tissue is in evidence. Uncomplicated injuries of these three parts of the bone are usually quite characteristic (Fig. 1336). The flat bones show a clean perforating wound

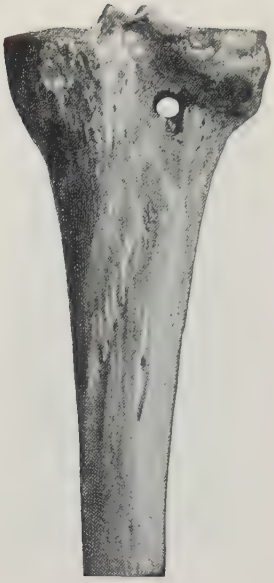


Fig. 1866.—Upper end of tibia penetrated by bullet, showing clean-cut wound without laceration of bone (La Garde).

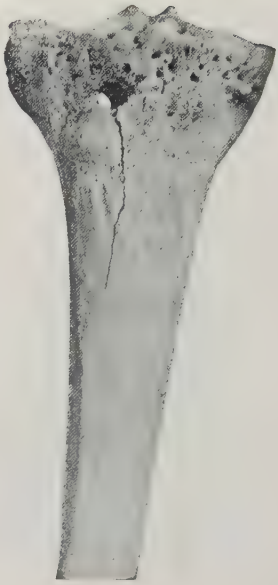


Fig. 1867.—Upper end of tibia penetrated by bullet. Slight fissure of shaft below bullet hole (La Garde).

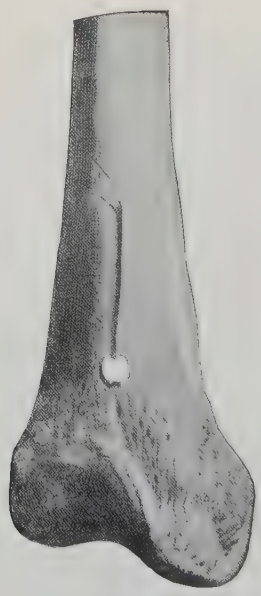


Fig. 1868.—Anterior surface of lower end of femur. Clean-cut wound of entrance, fissure (La Garde).

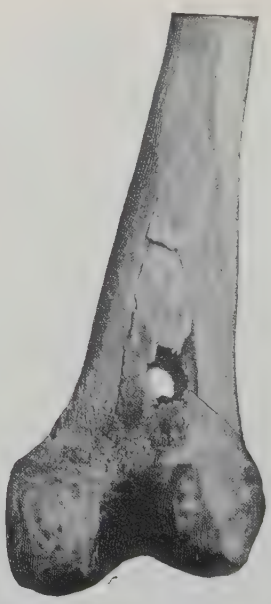


Fig. 1869.—Posterior view of Fig. 1868. Exit wound. Note more comminution than at point of entrance (La Garde).

similar to that seen in the short bones. The cancellous or spongy tissue of bone is ordinarily perforated completely and the wound of the bone is usually

pretty clean cut. Clean-cut perforations without fracture are the rule in the neighborhood of the joints and epiphyses (see Figs. 1866–1869). Makins noticed in South Africa, among the wounds he studied, "the striking contrast of clean perforation and extreme comminution in different cases"; "the occasional occurrence of fracture of a very high degree of longitudinal obliquity"; "the rarity of any that could be termed transverse fractures"; "the general tendency of longitudinal fissuring, when it occurred, to stop short of the articular extremities of the bones." If explosive effects are but slightly marked it is probably because the velocity remaining was insufficient to impart enough motion to the detached particles to convert them into secondary missiles. The greater the distance between the rifle and the bone struck, the lower will be the velocity of the bullet. Consequently, the splinters of bone will be fewer, longer, and more adherent. On the contrary, the nearer the bone to the rifle, the splinters will be more numerous, shorter, unattached, and pulverized with bone sand.

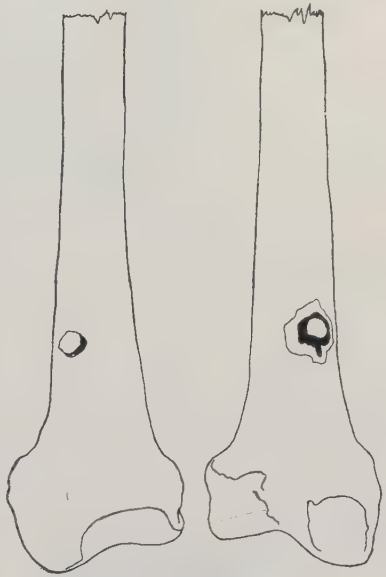


Fig. 1870.—Diagram of a bullet wound of the metaphysis of the femur. The smaller entrance wound contrasts with the larger exit wound. The absence of fissuring is rather characteristic of bullet wounds in this region of the ends of the bones (after Kocher).

A small skin wound may conceal a serious injury to the bone beneath. The flesh wounds of entrance inflicted by the modern rifle are mostly trivial. The missile with its great velocity, in face of slight resistance, will retain nearly all its energy, imparting little or none to the tissues. The exit wound may be small or large, depending upon the presence or absence of the explosive effect and also upon the deflection of the bullet. Deflection of the bullet at the distance at which many wounds are received, as pointed out by Nancrede, occurs more commonly than is taught. Between the discharge of a bullet and its arrival at the mark many things may happen to it, resulting in a complicated wound of the soft parts and an extensive comminution of bone.

The turning of a bullet by impact with an obstacle in its course is spoken of as ricochet. The bullet which ricochets may enter the body not necessarily end on, but in any position and wobbling about. Under these circumstances the wound of entrance is greatly increased, and, the velocity being impaired, a lodged bullet often results. However, if great velocity remains, a ricocheting bullet may cause very great damage. A ricochet bullet is dangerous because its penetrative power is diminished, it is liable to be retained in the tissue, serious damage results to the bone if it is struck, and a badly lacerated wound may result in the soft parts.

These facts are perhaps of interest: The old flint-lock ball was $\frac{7}{10}$ inch in diameter. The Minie rifle (Crimean) ball was $\frac{6}{10}$ inch in diameter. Martini Henry ball was $\frac{4}{10}$ inch in diameter. The modern small bore Lee-Metford is $\frac{3}{10}$ inch in diameter. The Mauser is slightly smaller than the latter. The latter two bullets have the new cupro-nickel case. The others were the old

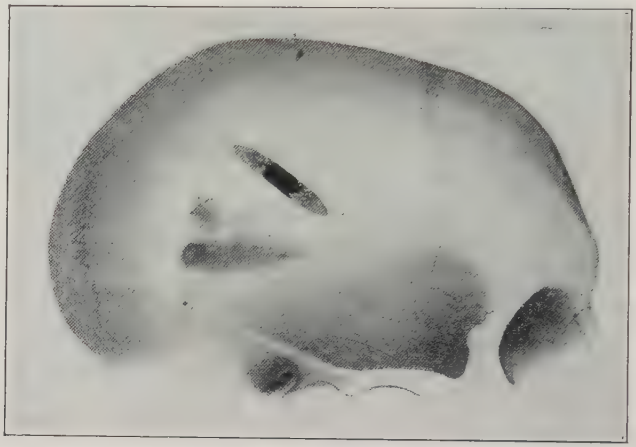


Fig. 1871.—Gutter fracture of second degree, perforating the skull in the center of its course. The external table alone carried away at either end (from Makins' "Surgical Experiences," etc.).

lead bullets. The Mauser bullet is 1.21 inches long, weighs 172.8 grains, is 0.275 inch in diameter, has a muzzle velocity of 238 feet per second, and makes one turn to the left every 9 inches. The English Lee-Metford is 1.25 inches long, weighs 215 grains, is 0.303 inch in diameter, and has a muzzle velocity of 2000 feet per second.

Fig. 1872.—Illustrating the penetrating power of bullets of different material in oak timber at right angles to grain of the wood (La Garde).

As La Garde has justly remarked, the employment of smokeless powder, a flatter trajectory and greater penetration, and the change to the smaller jacketed projectiles will increase the number of the wounded in war, but the wounds, as a whole, will be less grave—more humane. Soldiers will be more often restored to the State useful members of the community, instead of cripples and pensioners. In point of economy the new projectiles confer a great advantage.

Treatment.—The principles underlying the treatment of closed fractures are to be followed in the case of gunshot fractures. But there are a few considerations worthy of note. Avoid exploration of a fresh gunshot fracture upon the field. Local examination to determine the number, size, and position of fragments is unwise. The modern bullet is usually aseptic, smooth, and not heated. There is no urgency for its removal. It appears (Borden) that neither ricochet passage through other objects nor lowered velocity markedly increases the proneness of the jacketed missile to produce infection. The lodgment of a bullet does not necessitate the treatment of the wound as if it were an infected one. The dictum of von Nussbaum—"The fate of the wounded rests in the hands of the one who applies the first dressing"—applies nowhere with as much force as to the wounded in battle. The first field dressing is of the greatest importance.

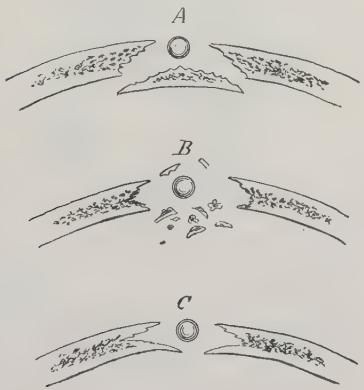


Fig. 1873.—Diagrammatic transverse section of complete gutter fracture: *A*, External table destroyed, large fragment of internal table depressed (low velocity or dense bone); *B*, pulverization and comminution of both tables at the center of the track; *C*, depression of inner table (low velocity) (from Makins' "Surgical Experiences," etc.).

Consideration of gunshot traumatism of the shaft of long bones, as shown by the Roentgen ray in connection with the ultimate outcome of the cases, points indubitably to the conclusion that infection or non-infection of the wound should influence treatment, rather than the amount or extent of bone damaged (Borden).

Infection in gunshot fractures is either from without the wound or from within the wound. If the infection is from without the wound, tincture of iodin as a disinfectant will prove effective. If the infection is from within the wound itself, tincture of iodin will prove to be of much less value (Blake).

In non-infected wounds extensive comminution is not, as a rule, an indication for operative interference of any kind. Occlusive dressings and immobilization give assurance of the best possible results. Where there is considerable comminution, shortening of the limb will probably occur as a result of the comminution and the displacement of the bone fragments. But excellent functional use of the limb may be restored unless the lesion

of the soft parts is extensive and motion is restricted by the formation of cicatricial connective tissue in the traumatic spaces (Borden).

Fig. 1874.—Clean gutter fracture of the ilium (range about 300 yards). The gutter was clean cut and admitted the forefinger. The inner and outer tables of the bone were in part blown out of a large, irregularly circular exit opening about 1½ inches above the crest of the ilium. The cancellous tissue was probably entirely blown out. Plates of the outer and inner tables still remained connected by their periosteum to that deep aspect of the iliacus and gluteus medius muscles. The peritoneal cavity was not opened. The patient did well. Compare with gutter fracture of the skull seen in Fig. 1871 (from Makins' "Surgical Experiences," etc.).

Where infection exists, removal of the cause under aseptic or antiseptic precautions is indicated. The primary operation upon a compound and

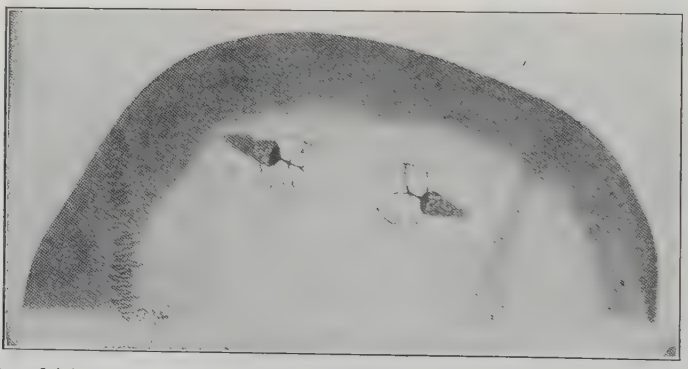


Fig. 1875.—Superficial perforating fracture, illustrating lifting of the roof at both entry and exit openings (from Makins' "Surgical Experiences," etc.).

gunshot fracture can ordinarily eliminate and prevent infection. A secondary suture of such a wound can be made successfully if infection is prevented. Secondary infections may accidentally arise (Blake). In such cases com-

plete débridement of the wound and removal of all absolutely loose bone fragments, followed by drainage and occlusive and sterile dressings, will usually suffice. The comminuted fragments of a gunshot wound are usually somewhat fixed to the periosteum and the surrounding muscular attachments. It was the general experience in the World War that apparently loose fragments of bone, if there was any appreciable attachment to the soft parts, should be left *in situ*. Early in the war union often was delayed and even prevented by the removal of loosely attached pieces of bone. Excision of joints or amputation will only have to be resorted to in extreme cases (Borden). Amputation for extensive fracturing of the long bones is almost unknown (Nancrede).

As to the disinfection of the limb, primary cleansing, mainly by soap and water, of course should precede the exploration; and when the latter has been carried out, a second cleansing, preferably with benzine, is imperative.

The employment of the Carrel-Dakin treatment will ordinarily control the initial infection. The Carrel-Dakin treatment must be employed exactly as described by Carrel, no modifications of it will be as successful as the original method.

Immobilization is a more difficult problem. Makins remarks: A question of constant difficulty is that of frequency of dressing. In a stationary or base hospital this is not difficult. When the patient is, however, being moved from the field to the stationary hospital, and thence to the base, the movements during transport disturb the fixity of the dressing. No fractures of the thigh or leg, and few of the arm, can be transported for any distance without material disadvantage. See splints for transportation of fracture of the upper extremity and lower extremity and note details of application.

If possible, all fractures of the arm, thigh, or leg should be kept at a stationary hospital for a period of three or more weeks.

The necessity for primary amputation chiefly depends on the nature of the injury to the soft parts, less commonly on the extent of the injury to the bones, and should be decided on exactly the same lines as in civil practice. So-called intermediate amputations are always to be avoided if possible. The results have been bad and the operation should only be undertaken in cases of severe sepsis where little can be hoped from it, or for secondary hemorrhage. When the operation could be tided over until the septic process had settled down and localized itself, secondary amputation gave very fair results. In either intermediate or secondary amputation for suppurating fractures it was necessary to bear in mind the special likelihood of an extensive osteomyelitis (Makins).

The very great mortality attending gunshot fracture of the femur previous to the introduction of the small-bore rifle makes it important to consider this fracture in some detail. I quote Makins as having had the best recorded clinical experience in these cases.

First, with regard to the primary signs and symptoms. A very considerable degree of general or constitutional shock usually accompanied them, and this was perhaps more constant than in the case of any other

injury in the body. Local shock to the part was also a prominent feature. Abnormal mobility was very free in the badly comminuted cases. Crepitus was often loose and of the "bag-of-bones" variety. The result of local shock and consequent flaccidity of the muscles was to reduce the development of primary shortening; in some cases of severe comminution this was practically

Fig. 1876.—Diagrammatic longitudinal section of fracture shown in Fig. 1875 (from Makins' "Surgical Experiences," etc.).

nil during the first day or two, when, with return of tone in the muscles, it sometimes became very considerable.

The long and difficult transport is the most unsatisfactory element to contend with in the treatment of fractures of bone in the field. There are advantages in having a field hospital behind the firing line. Sir William MacCormac has said that the ideal treatment of a gunshot fracture of the

Fig. 1877.—Perforation of lower third of tibia, showing lifting and fissuring of the compact roof of the tunnel. Compare with Fig. 1876, of a fracture of the cranial vaults (from Makins' "Surgical Experiences," etc.).

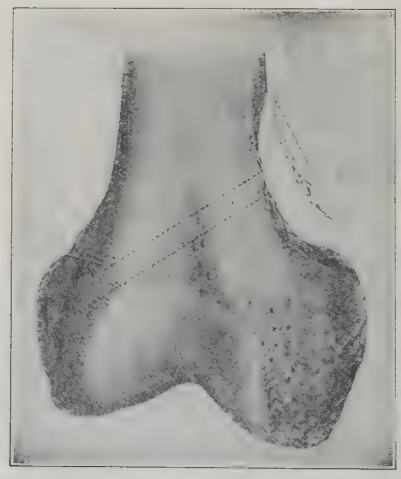


Fig. 1878.—Oblique perforation, implicating both epiphysis and diaphysis. Large fragment detached at exit aperture. Caused by a bullet traveling at a low rate of velocity. The dotted lines indicate the course of the track (from Makins' "Surgical Experiences," etc.).

femur would be to erect a tent over the man where he fell and not to transport him at all.

The operative mortality following compound or open fractures of the femur during the Crimean War was about 73 per cent. During the American War it was about 53 per cent. During the Franco-German War it was 65 per cent. among the Germans and 90 per cent. among the French. The con-

servative mortality—*i. e.*, in the unoperated cases—was, under these same conditions: Crimean War, 72 per cent.; American War, 49 per cent.; Franco-German: German, 28 per cent.; French, 9 per cent. In the war with Spain in Cuba, although the results are not all tabulated, during 1898–99 the general mortality in operated and unoperated cases together was but 10 per cent. in this serious injury. Modern surgical methods used upon wounds of bone caused by modern military weapons will bring the mortality rate very low indeed. All those interested in this department of surgery will await final statistics with hopeful expectation.

Prognosis in Fractures of the Femur.—From Makins' "Surgical Experiences": "As regards mortality, fractures in the upper third of the bone proved one of the most formidable injuries which came under treatment. Suppuration was common, at least 60 per cent. of the wounds becoming infected. This depended on several reasons, often inseparable from the injuries, or, from their treatment in field hospitals; such as (1) the exit wound being situated in the dangerous region of the thigh; (2) ineffective dressing and fixation; (3) the impossibility of insuring primary cleansing and removal of detached fragments of bone; (4) the necessity of the early transport of patients to the stationary or base hospitals, often for great distances; (5) the comparatively long period that often had to elapse before the opportunity of doing the first efficient dressing arrived. Fractures in the middle and lower thirds of the bone were more easy to treat successfully, but these also added to the list both of amputation and fatalities. Punctured fractures of the lower articular extremity were usually of little importance, as they progressed without exception, as far as my experience went, favorably."

CHAPTER XL

THE EMPLOYMENT OF PLASTER OF PARIS

MANY fractures of the upper and lower extremities may very properly be treated, at some period, by the plaster-of-Paris splint.

The plaster of Paris should be of the best quality and dry. Crinoline is used for bandages. Commercially it is called Arrowwanna Crinoline Lining. It is a lining material that is coarser meshed than the cheese-cloth used for gauze bandages, and is also stiffer than cheese-cloth. It should be cut into 4-yard lengths, folded, and stitched together. Crinoline contains considerable sizing or glue. This is detrimental to its use as a plaster bandage. It should, therefore, be washed of the sizing in lukewarm water, thoroughly rinsed, and rough dried. The stitching holds the material firmly together during the washing. It should then be cut into strips the widths of the desired bandages. Three widths are ordinarily useful, namely, widths of 2, 3, and $5\frac{1}{2}$ inches. These 4-yard strips are made into roller bandages. A fine-meshed gauze bandage is being used quite commonly in place of crinoline.

Rolling the Plaster.—It is a simple matter to make one's own plaster roller bandages. It is possible to purchase plaster bandages in sealed packages. These are ordinarily made with unwashed crinoline and are less desirable. A shallow box or tray is needed to hold the plaster. Two persons can roll the bandage with facility. "A" manages the roll of crinoline, straightens it as it unwinds, spreads the plaster with a light piece of board, the size of the hand, while "B" draws the crinoline across the tray from under the board held by "A," and rolls up the bandage loosely and evenly. "A," with the board held still and plaster heaped upon the bandage behind it, regulates, by more or less pressure upon the bandage, the amount of plaster distributed over the crinoline. It requires but ten or fifteen minutes to make enough bandages for a plaster splint for the leg or thigh. An advantage in making one's own bandages is that they are made of the desired width and have the proper amount of plaster. They are fresh and more likely, therefore, to set readily upon being wet. If many bandages are made at a time they may be kept in a tin cracker box. If the closed box is put in a dry place these bandages will keep indefinitely. Should the plaster become damp, the bandages should be placed in a warm oven until dry. It is important in making the plaster rollers to put just enough plaster into the bandage and to distribute the plaster evenly through the meshes of the crinoline. The proper amount of plaster to put into a bandage can only be learned by experience in making and using the bandages. It is a common error to spread the plaster too thickly. The water in which the bandages are dipped should be lukewarm and of sufficient depth to cover the bandages when set up on end. The water, working its way into the meshes of the bandages, displaces the air in the

Fig. 1879.—Shoulder-cap of plaster of Paris used in injuries to the shoulder-joint and upper end of humerus. Note shape of crinoline, which has been filled with plaster cream. First step in application. The shoulder may be covered with a protective layer of sheet wadding.

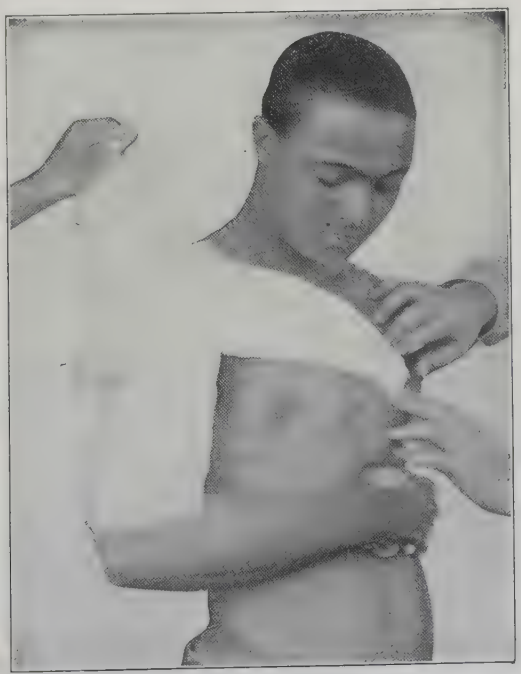


Fig. 1880.—Shoulder-cap of plaster of Paris. Application to shoulder and front of chest. Second step in application. Note that shoulder and upper arm are well covered.

Fig. 1881.—Shoulder-cap of plaster of Paris. Application completed. Anterior view.

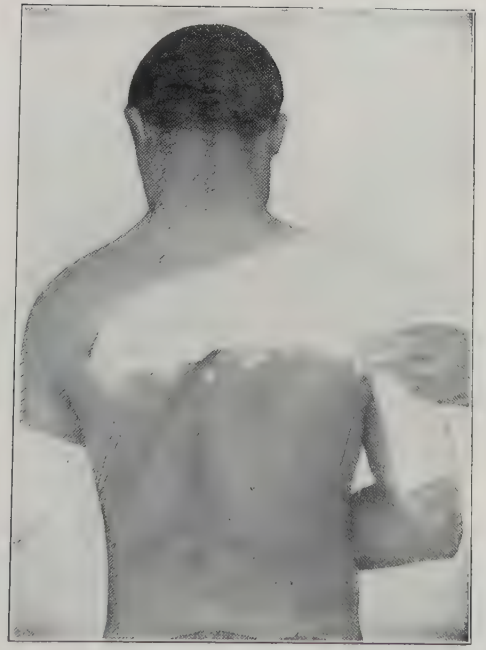


Fig. 1882.—Shoulder-cap of plaster of Paris. Application completed. Posterior view.

Fig. 1883.—Shoulder-cap of plaster of Paris. Application of retentive roller bandage of cheese-cloth. Anterior view. A sling should complete the dressing.

bandage, which is indicated by the bubbles rising to the surface of the water. As soon as the bubbles have stopped rising the plaster is thoroughly wet throughout the bandage. Table salt, 2 teaspoonfuls to 4 quarts of water, hastens the setting of the plaster. Its use, however, is to be deprecated, because the plaster has to be applied too quickly for the best results in plaster work, and the brittleness of the plaster resulting from the use of salt is undesirable. The plaster bandage should be lifted from the water carefully with both hands holding the two ends so as to retain as much plaster as possible within the roll. The bandage should then be wrung free from water

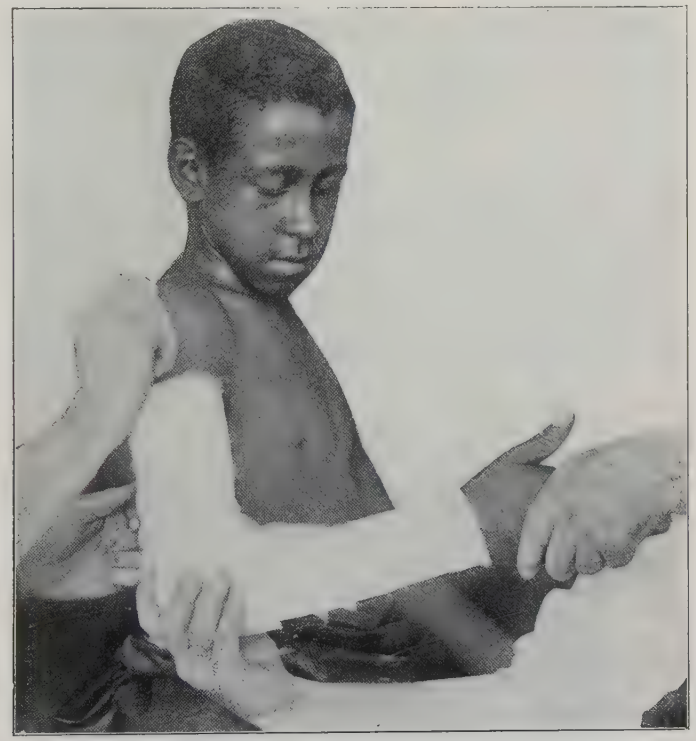


Fig. 1884.—Fracture of the elbow or forearm. Application of sheet wadding for protection. Method of holding the arm at a right angle.

while the hands still grasp its ends. The bandage should be wrung until it does not drip. In the application of the plaster splint to fractures of any part of the body it is important that all deformity should be corrected and that the part should be thoroughly immobilized. This necessitates the presence of one or two assistants.

In applying a plaster splint with the roller bandage the surgeon should do his work so carefully that he scatters no plaster anywhere but upon the splint and in the pail of water. The surgeon should work neatly. The patient should be protected by a sheet. The floor should be protected by a sheet spread under the patient and under the chair of the surgeon. The

Fig. 1885.—Fracture of the elbow or forearm. Application of plaster-of-Paris bandage. Method of holding the arm.

Fig. 1886.—Fracture of the elbow or forearm. Plaster-of-Paris splint being applied. Elbow at a right angle.

surgeon should remove his coat, roll up his sleeves, and be protected from unexpected spattering of plaster by an apron or sheet over his body.

One thickness of sheet wadding torn into strips, from 3 to 5 inches wide, and rolled into roller bandages and then applied to the limb forms the best

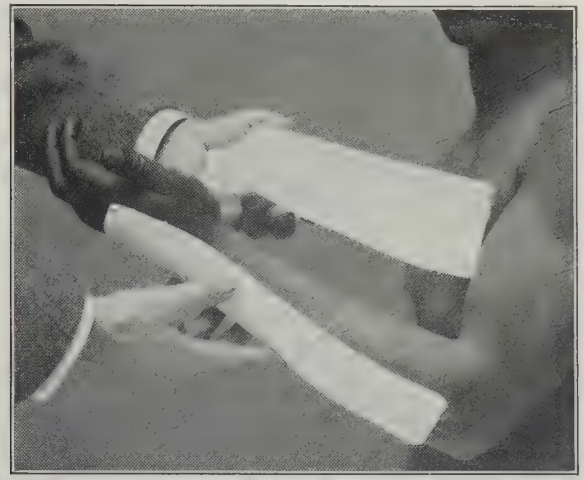


Fig. 1887.—Anterior and posterior splints being applied after having become firm upon the forearm. For fracture of forearm bones.

protection to the skin in applying the plaster splint. The sheet wadding is purchased at any of the dry goods stores. It may be purchased by the quarter

Fig. 1888.—Anterior and posterior splints in position. To be held in place by adhesive-plaster strips and a bandage. A light, durable, cheap, efficient splint.

bale or by the single sheet. The plaster bandage should be applied to the protected part slowly, deliberately, and accurately. The bandage should

be applied smoothly, and should have no wrinkles or thick awkward places anywhere. It is well to rub the bandage as fast as it is laid upon the part with

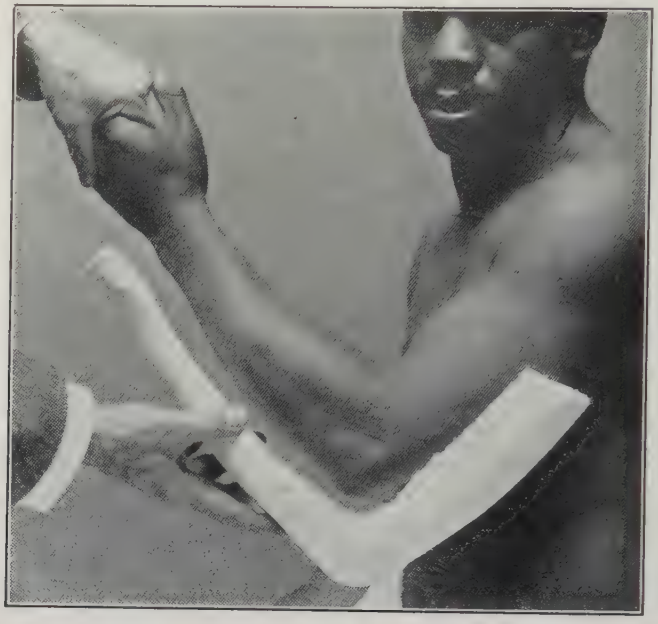


Fig. 1889.—A posterior splint for elbow, forearm, and upper arm. It is most comfortable.

Fig. 1890.—Posterior elbow splint in position.

the palm of the hand slightly wet to distribute the plaster cream thoroughly and evenly. Over bony prominences the bandage should be very carefully molded. This will insure a good fit and less likelihood of slipping upon

change of position. It is well to carry the first roll of plaster as far as it will go, one or two layers thick, completing the whole splint once, and then to

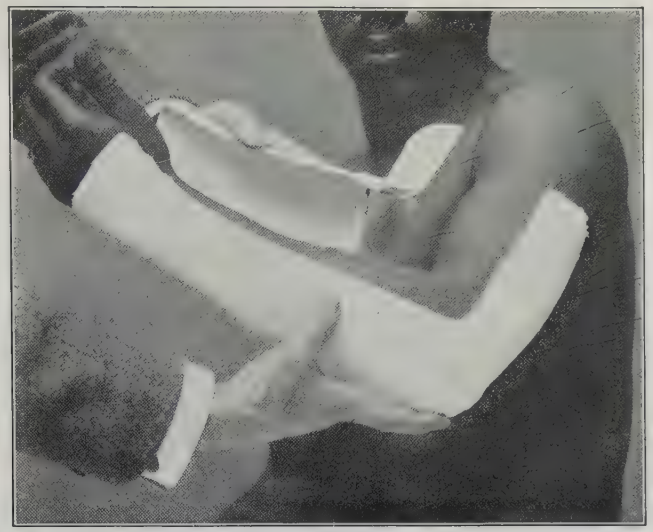


Fig. 1891.—Posterior and anterior splints for elbow. Anterior splint being applied.

go over it again from beginning to end. A sufficient number of layers should be applied to make a firm enough splint for the support of the part when the

Fig. 1892.—Anterior and posterior splints for the elbow. Note the additional plaster wedge being put in place to strengthen the anterior splint at the bend of the elbow.

plaster has set. The splint should be as light as is compatible with strength. Light splints, if accurately fitted, accomplish more good than heavy, ill-

Fig. 1893.—Anterior and posterior plaster splints applied. Most comfortable and efficient in injuries high up the forearm and at the elbow and lower part of upper arm.

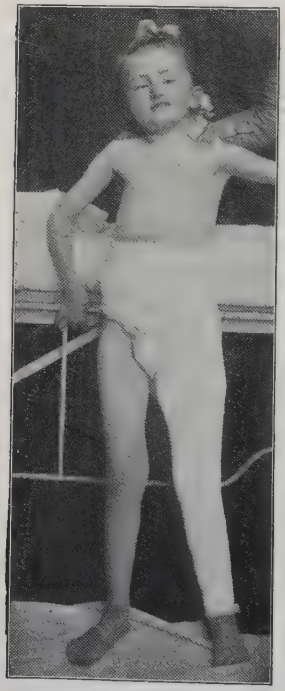


Fig. 1894.—Plastic spica dressing of service after fracture of the femur when the patient is first up.

Fig. 1895.—Plaster spica shortened to permit flexion of the knee after fracture of the femur.

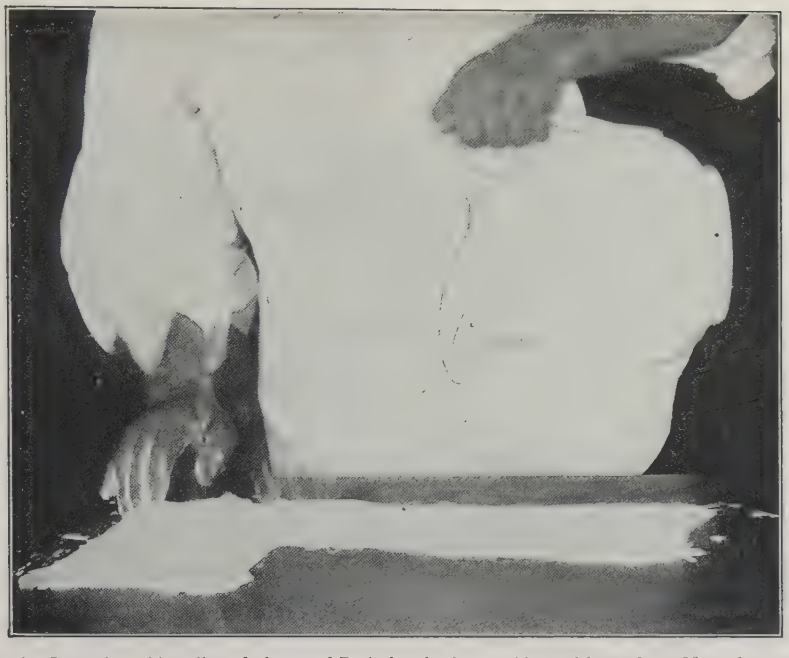


Fig. 1896.—Lateral or side splint of plaster of Paris for the foot, ankle, and lower leg. Note shape of crinoline. The plaster cream is being poured from pitcher and evenly rubbed into the layers of crinoline.

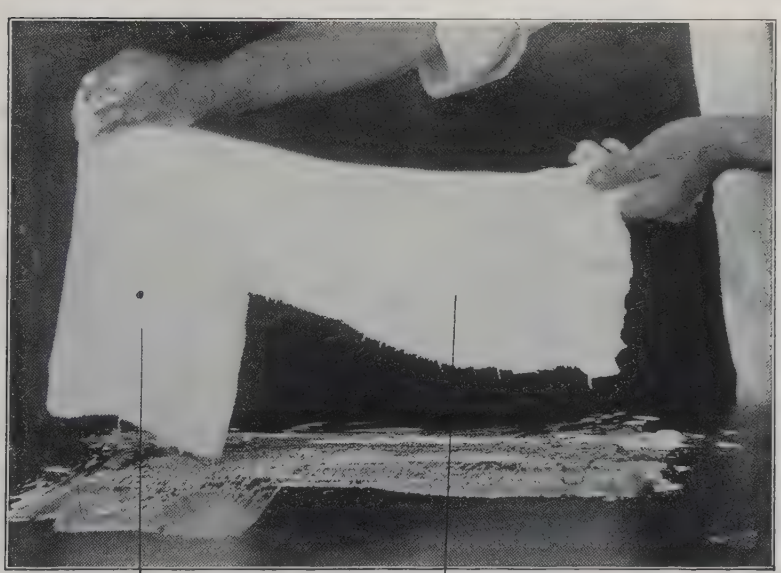


Fig. 1897.—Lateral or side splint of plaster of Paris ready for application to leg, ankle, and foot. Plaster cream has been thoroughly rubbed into the meshes of the crinoline.

fitting ones. It is better to use too few rolls of plaster bandage rather than so many that a heavy and cumbersome splint is made. Immediately after

the plaster has set, if it is found to be too weak at any spot, an additional bandage may be used to reinforce at that point. The part bandaged should

Fig. 1898.—Lateral or side splint of plaster of Paris applied to the inner side of leg, ankle, and foot. Held in position ready for bandage. Note the perforated tin strip at the ankle for greater strength. Foot at right angle with leg.

be held in perfect position until the plaster has set firmly enough to support it. This will ordinarily occur in about ten or fifteen minutes. The weight of the splint may be materially reduced by using tin strips incorporated in

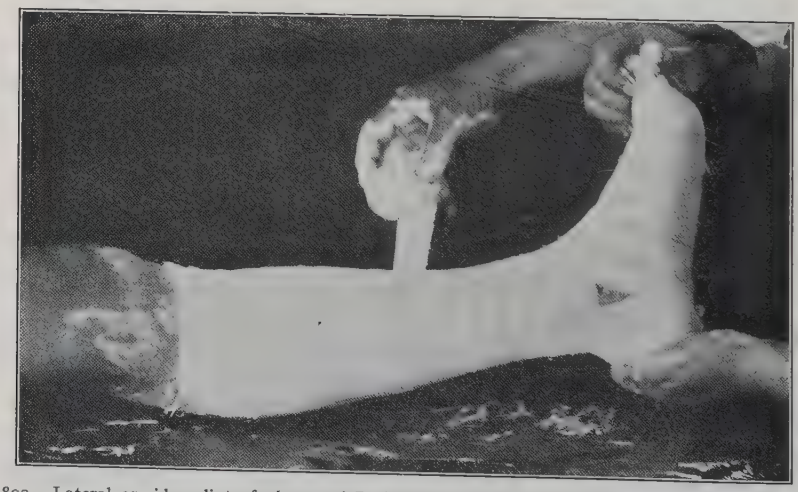


Fig. 1899.—Lateral or side splint of plaster of Paris. Retentive bandage being applied. Tin reinforcing strip seen at the ankle.

the layers of the plaster bandage. These strips should be perforated by holes so as to offer rough places to catch in the plaster bandage. The two ends of the splint should be so finished that pressure and consequent deform-

ity cannot occur—for instance, the plaster of the forearm should stop just short of the bend of the elbow. The plaster of the thigh should be so far below the perineum and groin as to permit of flexion of the thigh upon the

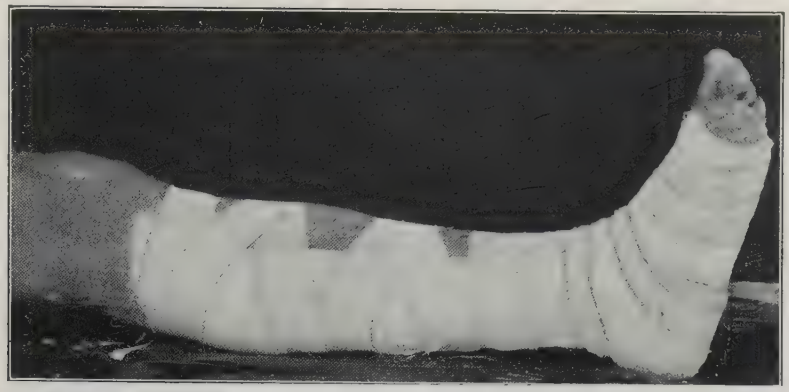


Fig. 1900.—Plaster gutter to posterior surface of leg and foot, held in place by a few turns of a cheese-cloth bandage. This plaster posterior splint is made much as is the lateral plaster splint for the leg and foot.

trunk without excoriating the skin of the groin. The toes and fingers should be left uncovered to admit of inspection.

A certain degree of skill is demanded upon the part of the surgeon for the proper application of the plaster-of-Paris splint. Plaster of Paris, when

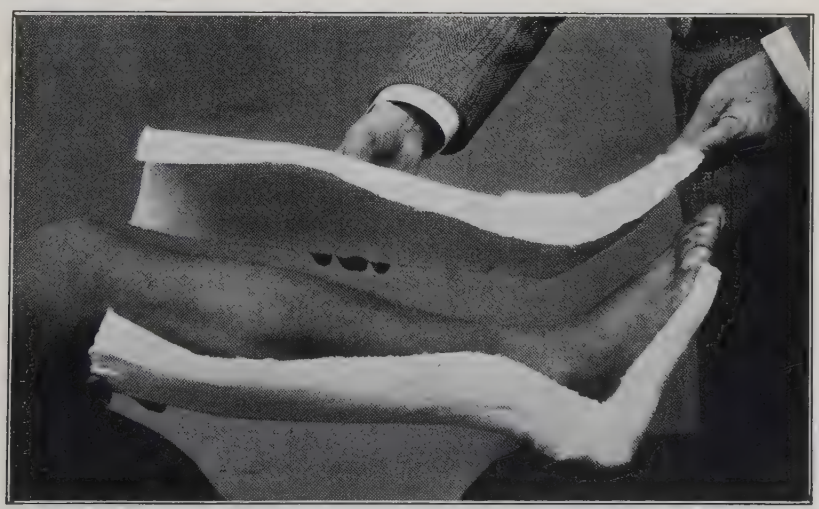


Fig. 1901.—Anterior and posterior plaster splints for injuries to the leg below the knee and about the ankle and foot. Anterior splint being applied.

used for fractured bones, is applied either before or after the swelling has taken place; if applied before, it constricts the seat of fracture, prevents swelling, and may cause great pain; if applied after the swelling has taken

place, it becomes loose as soon as the swelling of the soft parts subsides, and motion of the limb in the splint and of the fragments of the fractured bone one upon the other is possible. It is important, therefore, to split the plaster

Fig. 1902.—Anterior and posterior leg splints applied. Note application of the half-cuff of plaster to reinforce the ankle.

soon after it has been applied, and thus obviate these dangers of too light and too loose a splint. The tightness of the splint should be regulated by straps and a bandage of cheese-cloth.

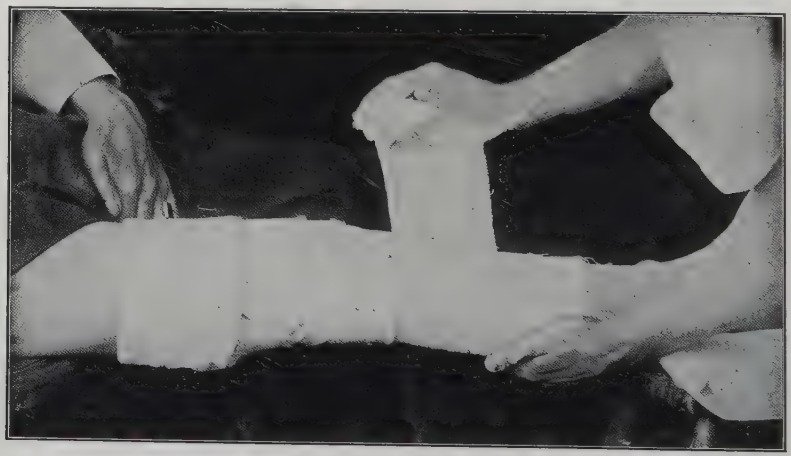


Fig. 1903.—Fracture of the patella. The leg covered with sheet wadding. The application of the plaster-of-Paris roller.

The Removal of the Plaster Splint.—The removal of the plaster splint is difficult. No instrument has been devised that is more efficient than an ordinary sharp jack-knife. If the plaster splint is split immediately after its

application—*i. e.*, as soon as it is hard—it will be far easier than if it is cut after it is thoroughly dry. A strip of tin 1 inch wide laid upon the protected leg and covered by the plaster in its application will often be of great service upon removing the plaster. The tin will serve as a protection to the skin, and the cutting may be done more quickly and easily.

Fig. 1904.—Fracture of the patella. Application of the plaster-of-Paris roller. Bandage being finished.

After removing most of the plaster from his hands the surgeon should wash his hands with a little water and granulated sugar or molasses. The sugar assists in removing all traces of plaster and leaves the skin soft and clean. Bandages of plaster of Paris are so readily obtained, so efficient, so

Fig. 1905.—Fracture of the leg. Plaster-of-Paris splint applied from the toes to the groin. Foot at a right angle with the leg. Toes padded to prevent chafing.

safe from interference upon the part of the patient, and so easy to apply that it is surprising they are not applied more often than they are.

The **dextrin bandage** is much slower in becoming firm than the plaster bandage, and yet is very light and serviceable. It is applied exactly as

Fig. 1906.—Fracture of the leg. Plaster cast of leg from toes to below the knee removed.

Fig. 1907.—Fracture of the leg. Removable plaster cast of leg. Same as Fig. 1906. Anterior view, showing cut in plaster.

is the plaster-of-Paris bandage. The roller bandage of cotton cloth is first unrolled and rerolled in a basin containing a watery solution of powdered

Fig. 1908.—Open fracture of the leg. Plaster-of-Paris splint. Window cut in plaster, through which wound is dressed. Window surrounded by oiled silk.

dextrin. Formula for making the solution of dextrin: Add about 14 ounces of powdered dextrin to a pint of water, boil until dissolved, strain, and add

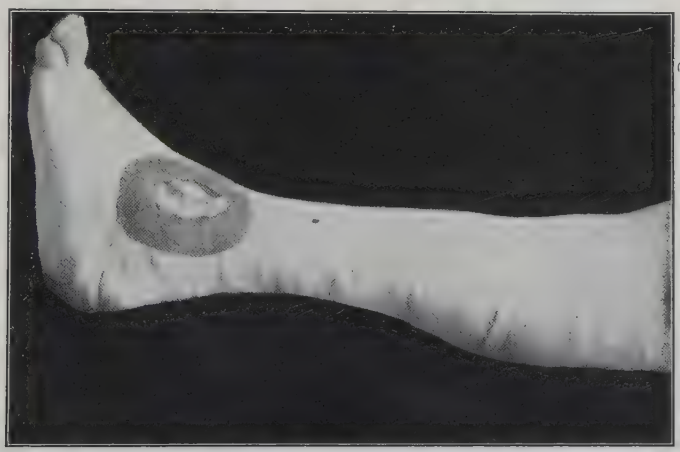


Fig. 1909.—Open fracture of the ankle. Window in plaster-of-Paris splint, through which wound is dressed. Gauze seen in the window. Oiled silk about the window.

1 ounce of alcohol. The bandage is, therefore, thoroughly saturated with the dextrin solution. After covering the part bandaged once, dextrin is painted, with a small paint-brush, over the bandage. This is allowed to dry

Fig. 1910.—Ham splint of plaster of Paris. The splint is slightly thicker at the ham underneath the region touched by the thumb in the plate. It is thus strengthened. More comfortable than ordinary wooden ham splint.

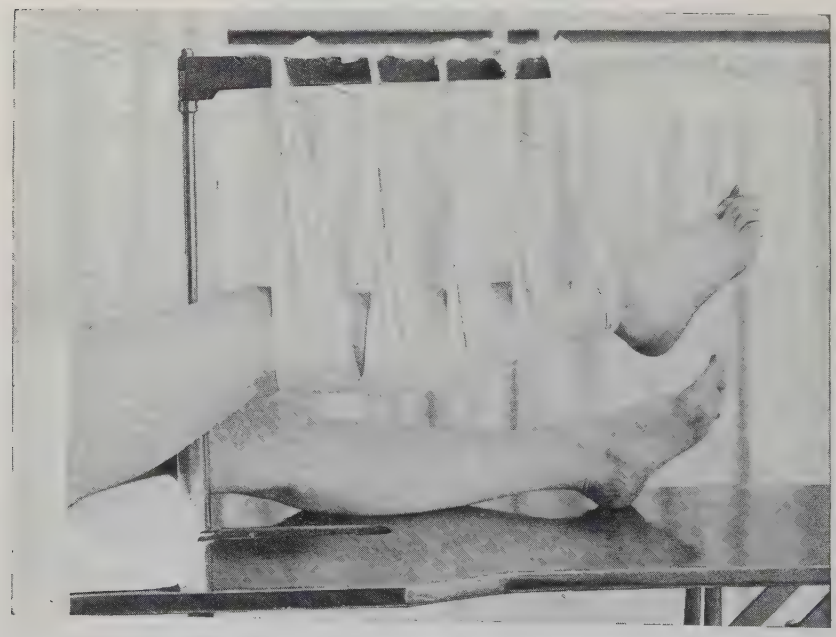


Fig. 1911.—Method of preventing posterior bowing in fracture of both bones of leg when applying a cast. Showing piece of muslin wide as leg is long, torn into 3-inch width strips, leaving a continuous piece in middle. The leg is then tied up to a horizontal support above. (From Magnuson and Coulter, in International Clinics, Vol. I, Series 31. J. B. Lippincott Co., Publishers.)

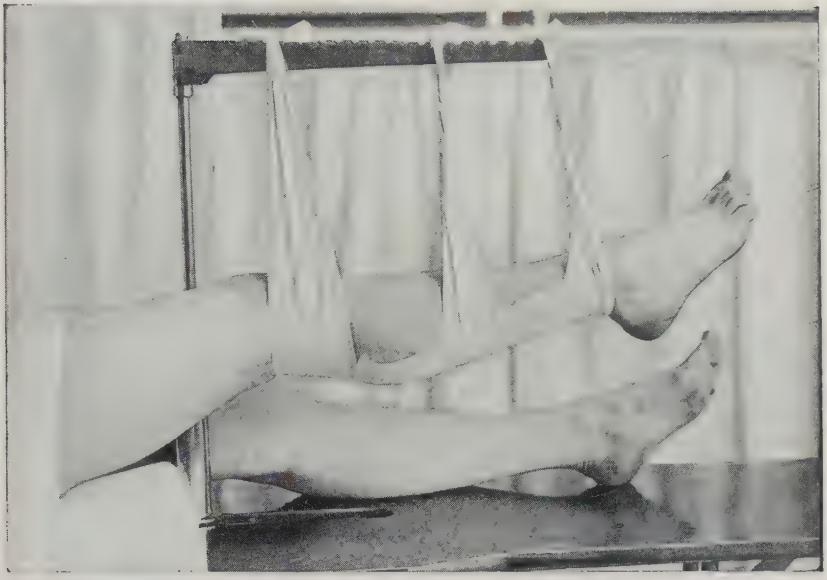


Fig. 1912.—Method of preventing posterior bowing when applying a cast for fracture of both bones of the leg, showing the alternate strips cut. (From Magnuson and Coulter, in International Clinics, Vol. I, Series 31. J. B. Lippincott Co., Publishers.)

Fig. 1913.—Device to prevent cast applied for fracture of both bones of leg from rotating out. Note piece of board placed on posterior part of cast, held by few turns of plaster bandage. This holds the lower fragment in the proper arc of rotation to meet the normal rotation, Fig. 1914. (From Magnuson and Coulter, in International Clinics, Vol. I, Series 31. J. B. Lippincott Co., Publishers.)

before a second and third layer of the bandage are applied. After each bandage a coating of dextrin is applied. After the final bandage several coatings

Fig. 1914.—Of the upper fragment. Note this holds leg in normal weight line position—anterosuperior spine—middle of patella and second toe. (From Magnuson and Coulter, in International Clinics, Vol. I, Series 31. J. B. Lippincott Co., Publishers.)

of dextrin are applied until a shiny, smooth surface results. This bandage may be cut, and, by the addition of strips of leather along the cut edge upon

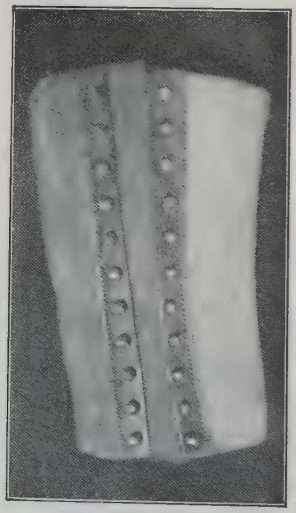


Fig. 1915.—Fracture of the patella. Leather knee-cap with hooks for lacing. Made from plaster cast. Worn as a protection to knee after fracture.

which are hooks, may be laced and unlaced as necessary (Figs. 1916, 1917).

Fig. 1916.—Fracture of the leg. Removable dextrin splint with hooks and lacing.

Fig. 1917.—Fracture of the leg. Same as Fig. 1916. Anterior view.

It is important for every surgeon who may handle fractures to understand the use of plaster of Paris as splint material. If it is used intelligently it is valuable, if it is used unintelligently it may be the occasion of irreparable damage. It must be remembered that after applying a plaster-of-Paris splint the limb is rigidly encased, held immovable. The muscles of the part no longer can readily contract. Consequently the circulation is hindered. An edema will result. When the lower limb is allowed to be dependent under the above conditions necessarily there will result an increasing edema. This may become not only uncomfortable, but a real menace to the circulation of the part. If the limb is kept elevated for twenty-four hours immediately after the application of the splint, less swelling will occur subsequently than if the plaster-of-Paris encased limb is permitted to hang down. In the case of the upper extremity the hand and elbow should be allowed to rest at a little higher level than the shoulder. In the case of plaster-of-Paris splints applied to the lower extremity, not including, of course, the plaster-of-Paris spica splint encircling the pelvis and the lower extremity, the foot should be elevated immediately after the application of the splint to a level a little above the hip of the same side.

All circularly applied plaster-of-Paris splints should be split or cut into two portions immediately after their application. Thus will be avoided dangers of constriction of the part and consequent disturbances of the circulation.

CHAPTER XLI

THE AMBULATORY TREATMENT OF FRACTURES

By the ambulatory treatment of fractures of the lower extremity is understood a method of treatment that permits the immediate and continued use of the injured limb as a means of locomotion.

Medical literature contains many references to this method. It has been in use for many years. It has not met with general acceptance even among hospital surgeons. It is a radical method and open to criticism. It contains, however, several important suggestions. It will prove instructive to follow the adoption of this method by its advocates, and to discover, if possible, what there is in it of permanent value.

Orthopedic surgeons as early as 1878 conceived the idea of allowing a patient with a fracture of the thigh or of the leg to walk about by means of apparatus. Thomas, of Liverpool, and Dowbrowski used the Thomas knee-splint in the treatment of fractures certainly as early as the year 1881 or 1882. Krause, a German surgeon, published in 1891 the first account of the treatment of fractures of the bones of the leg in walking patients. Krause demonstrated that plaster of Paris could be used as a splint in fractures of the leg and in transverse fractures of the thigh. Korsch in 1894 presented a paper to the German Surgical Congress demonstrating that compound fractures of the leg and fractures of the thigh may be treated with plaster-of-Paris splints and early use. Korsch makes permanent extension in a thigh fracture, while traction is maintained by an assistant, by applying the plaster directly to the skin, snugly to the malleoli, the dorsum of the foot, and the heel. A padded ring is incorporated into the upper limit of the plaster splint around the thigh, which presses against the tuberosity of the ischium, and thus accomplishes counterextension. Korsch's cases were treated in Bardeleben's Clinic. Bruns, of Tübingen, in 1893 described a splint for use in these cases of fracture of the leg and thigh. Dollinger, of Budapest, in 1893 described a splint for the ambulatory treatment of fractures of both bones of the leg, and reported 3 cases. Dollinger's method of applying the plaster-of-Paris splint is the one generally used whenever the ambulatory treatment is employed. The method is described later.

Warbasse, at the Methodist Episcopal Hospital at Brooklyn, N. Y., in 1893 was the first in this country to adopt systematically Dollinger's method. Warbasse reports 6 cases—all in young adults. Bardeleben reported in 1894 116 cases treated with walking splints. There were 89 fractures of the leg, complicated and uncomplicated; 5 fractures of the patella; 22 fractures of the thigh, 5 of which were compound; 3 cases of osteotomy for genu valgum. Bardeleben lays down the following law: "It is of the greatest advantage to the patient that such a dressing can be applied to the broken leg that he

can bear the weight of the body upon it and walk about; but such a method of treatment should be applied only under medical supervision, and with the most careful consideration of complications that might arise." Korsch presented to the German Surgical Congress in 1894 7 cases—3 of the thigh and 4 of the leg. Albers in 1894 reported 78 cases (56 of the leg, 5 of the patella, 16 of the thigh, and 1 of the leg and thigh) treated by the ambulatory method. He seems to be a little more cautious than other German surgeons in this matter. He says that when great pain is present it is best to employ injections of morphin.

Elevation of the limb will often reduce the swelling; when this does not suffice, the bandage must be removed. Severe local pain from pressure indicates the necessity for cutting a fenestrum. The first attempt at walking should be made on the day following the application of the cast. A crutch and cane are used at first; later, two canes are employed; and, finally, some patients walk without any support at all. Krause in 1894 reported 72 cases treated. He is of the opinion that the ambulatory treatment in plaster splints must be limited principally to fractures and osteotomies in the region of the malleoli, the leg, and the lower end of the thigh. He does not employ the method in the handling of oblique fracture of the femur and fractures of the neck of the femur. Bardeleben writes again in 1895, reporting up to that date 181 cases treated by the ambulatory treatment. This last report, of course, included the 116 cases of the previous record. Dr. Edwin Martin, before the Surgical Section of the College of Physicians of Philadelphia, in December, 1895, reported 20 cases of fracture of the leg treated by this method. Dr. E. S. Pilcher, of Brooklyn, N. Y., in whose wards Warbasse worked, reported to the American Surgical Association the 20 or more cases treated by him in which the results were satisfactory. N. P. Dandridge, of Cincinnati, Ohio, has used the method in 8 cases. In most of the cases pain was complained of when weight was borne on the foot. In a feeble woman it was necessary to remove the cast in the third week. In the case of a man—a compound fracture of the leg—after walking two weeks he had so much pain that the plaster was removed. Redness and swelling were great at the seat of fracture, and there was much swelling over the internal malleolus. Woodbury introduced the method at Roosevelt Hospital, New York City, and Fiske has reported cases treated at that clinic. Roberts, of Philadelphia, and Woolsey, of New York, have used the method in selected cases with satisfaction. A. T. Cabot, of Boston, has used, in several fractures of the femur, Taylor's long hip-splint. E. H. Bradford, of Boston, has treated cases of fracture at the Children's Hospital by a modified Thomas knee splint, with and without plaster-of-Paris splinting (Fig. 1918).

Those advocating the ambulatory treatment suggest its application to fractures of the leg below the knee, both simple and compound, and in fractures of the lower end of the femur. The apparatus is not to be applied for three or four days if there is much primary swelling.

The **method of application of the plaster splint in the ambulatory treatment of fractures** of the tibia and fibula alone is as follows (this is practically

the method of Dollinger): First comes the cleansing of the skin of the leg with soap and water and then the reduction of the fracture. Then, with the foot fixed at a right angle to the leg, a flannel bandage is smoothly and evenly applied from the toes to just above the knee. This bandage is made to include beneath the sole of the foot a padding of 10 or 15 layers of cotton wadding, making a pad about $\frac{3}{4}$ inch thick, after it is compressed by the moderate pressure of the flannel bandage. Over this is now applied the plaster bandage from the base of the toes to just above the knee, especial care being taken that the application is made smoothly and somewhat more

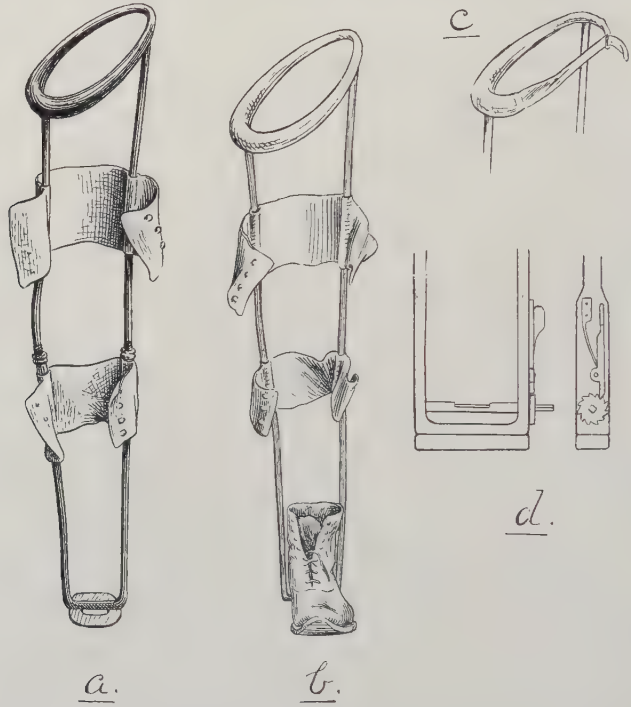


Fig. 1918.—Thomas knee-splint or ambulatory treatment of leg fractures, used with a light plaster-of-Paris leg splint: *a*, Ordinary form; *b*, "caliper" or convalescent splint so fitted as to keep the heel of the foot away from the boot while the toes are used; *c*, the half-ring sometimes used at the upper end; *d*, lower end of splint, as arranged for windlass traction.

firmly than is the custom in the ordinary plaster cast. The layers of the bandage should be well rubbed as they are applied, with a view to obtaining the greatest amount of firmness with the smallest amount of material. The sole is strengthened by incorporating with the circular turns an extra thickness composed of 10 or 12 layers of bandage well rubbed together, and extending longitudinally along the sole. The bandage is applied especially firmly about the enlarged upper end of the tibia, and here it is made somewhat thicker. As it dries it may be pressed in so as to conform more closely to the leg just below the heads of the tibia and fibula. The assistant, who stands at the foot of the table and supports the leg, makes such traction or

pressure as is required to keep the fragments in proper position while the plaster is being applied. The operation requires about twenty minutes, and by the time the last bandage is applied the cast should be fairly hard.

It is seen that when this cast has become hardened the leg is suspended. When the patient steps upon the sole of the plaster cast the thickness of the cotton beneath the foot separates the sole of the foot so far from the sole of the cast that the foot hangs suspended in its plaster shoe. Thus the weight of the body, which would come upon the foot, is borne by the diverging surface of the leg above the ankle. The chief of these is the strong head of the tibia. A lesser rôle is played by the head of the fibula and the tapering calf in muscular subjects.

In thigh fractures the use of the long Taylor hip-splint, together with a high sole upon the well foot and crutches, is generally accepted as the best method of ambulatory treatment.

The *advantages* claimed for the ambulatory method are:

Time is saved to the business man by this method—he having to give up but about seven days to a fracture of the leg. The time spent by the patient in the hospital is less than by other methods. The general health is conserved; whereas by the old method the appetite is variable, sleep is troubled, the bowels are constipated, and general discomfort prevails. There is greater general comfort by this method than by any other. In drunkards and those with a tendency to delirium tremens this liability is greatly diminished. In old people the danger of a hypostatic pneumonia is lessened. The primary swelling associated with a fracture is often avoided, and always less than by the older methods. The secondary edema and muscular weakness are less. The functional usefulness of the whole leg is greater. There is less atrophy of the muscles of the thigh and leg. The amount of the callus is diminished. There is less stiffness of neighboring joints. Union in a fracture occurs at an earlier date.

Before this method can be adopted generally and in hospital treatment it must be demonstrated that it is safe, and that it offers chances of better functional results than are obtained under present methods, and that the minor advantages claimed for it by ardent German advocates are real and not imaginary. The first great advantage of the method is stated to be that the stay in the hospital and the time away from one's occupation are much lessened. Regarding this point the Massachusetts General Hospital Surgical Records were consulted for these three periods: before the use of plaster of Paris—that is, previous to 1865; just at the beginning of the use of plaster of Paris as a splint for fracture, and in 1895, 1896, and 1897. Thirty-five unselected cases of fracture of the tibia and fibula were tabulated from each period. The duration of the average time spent in the hospital in the first period—*i. e.*, previous to 1865—was forty-six days; in the second period—*i. e.*, about 1866—it was forty-five days; at the present time it is sixteen days. In the second period plasters were applied to fractured legs on an average at about the twenty-eighth day; at the present time, on the fourteenth day. In other words, there has been since the introduction of the plaster splints

a gradually shorter detention in the hospital, as surgeons have come to recognize the safety of an earlier application of a fixed dressing. On an average, patients with fracture of the leg are detained in the hospital today but sixteen days. The very great saving to the hospital in time by the ambulatory treatment does not, therefore, appear. It is impossible to consider the statements made with regard to rapidity of healing, sign of callus, absence of muscular atrophy, and absence of rigidity of joints, because there are no facts available for the purpose. The advantages stated are based, most of them, upon the personal impressions of the surgeon in charge; impressions compared with scientific observations are untrustworthy.

Krause presents a table from Paul Bruns containing the average periods of healing in a series of fractures, and compares these periods with his own fracture cases treated by the ambulatory method. This is the only attempted scientific statement of observation on this important point. Krause concludes from a study of these tables that, "In the treatment of fractures of the middle and upper thirds of the leg the ambulatory method shows a great advantage in the period of consolidation as well as in the time when the patient can return to work. It seems that the higher up the fracture is in the leg, the sooner a cure is effected by the ambulatory method of treatment."

Conclusions.—A review of the literature does not disclose any other advantage in the results of the ambulatory treatment over the present treatment of fractures of the leg than that stated by Krause. The present commonly accepted method of treating fractures of the femur by long rest in the horizontal position, with extension by weight and pulley, is not satisfactory. The protracted stay in bed is undesirable. The use of the Taylor hip-splints in the treatment of this fracture, assisted by coaptation splints or a splint of plaster of Paris, is of distinct value. This, however, is a somewhat well-known method of ambulatory treatment.

Theoretically and practically the ambulatory treatment does not perfectly immobilize; therefore it cannot pre-eminently succeed as a means of treatment. The method in general seems to be unsurgical. Embolism, both of fat and blood, and the likelihood of pressure-sores in the use of the plaster splint are dangers to be considered. It is wise to allow the injured limb to rest while the reparative process is beginning. Muscular relaxation is desirable in the treatment of fractures. The very admission by the advocates of the ambulatory treatment that muscular contractions take place is reason enough for supposing that complete immobilization is not obtained by this method. However, in certain carefully selected cases of fracture below the knee, particularly of the fibula, if under the care of a competent and skilful surgeon, it is possible to conceive of the ambulatory method being used without doing harm.

A consideration of the ambulatory treatment of fractures should lead to a more careful and early use of the plaster-of-Paris splint in fractures of the leg, and to a proper application of the long hip-splint or its equivalent in fractures of the thigh, and to the early use of crutches and the high sole on the well foot in both of these lesions.

CHAPTER XLII

NOTES UPON A FEW DISLOCATIONS

DISLOCATION OF THE CERVICAL VERTEBRÆ

This dislocation may be either bilateral or unilateral. The bilateral form, in which both the articular processes slip forward or backward over those below, is of comparatively infrequent occurrence. It is attended by marked symptoms of pressure upon the spinal cord. A fatal termination is

Fig. 1919.—Dislocation of right articular process; head turns to left. Head also bent to left because process is caught. Left sternocleidomastoid relaxed. Right sternocleidomastoid tense and stretched (Walton).

the usual outcome of a bilateral dislocation, although this is not always the case.

The most common form of cervical dislocation is that occurring upon one side, and is usually without fatal result. This is rather a common injury. It is often unrecognized. In this unilateral dislocation of the cervical vertebræ an articular process slips over the articular process below it and either catches upon the top of the lower articular process or slips down in front of it. This displacement causes the head to tip over to one side and to rotate sidewise. The immobility of the head, the peculiar position of the head, simulating a torticollis; the relaxation of the muscles of the neck—the contraction of which muscles would have produced the deformity;

the taut condition of the muscles upon the opposite side of the neck—these signs are diagnostic of a dislocation, of a unilateral dislocation of a cervical vertebra.

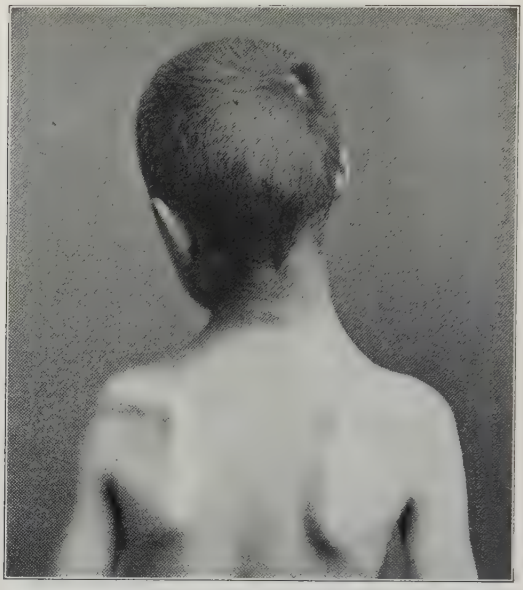


Fig. 1920.—Right unilateral dislocation. Note tipping of the head to the left and atrophy of the supraspinatus and infraspinatus muscles on the left side (Walton).

To illustrate definitely: Suppose that the right articular process slips forward and over the corresponding articular process of the vertebræ below it and has fallen into the hollow in front of that process. The head will be

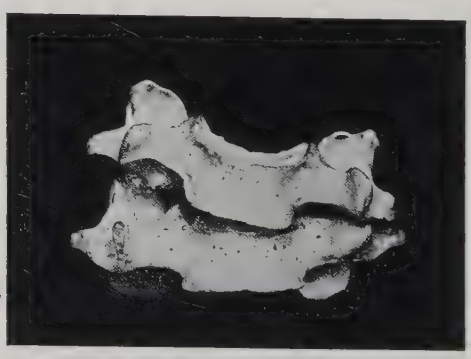


Fig. 1921.—Cervical vertebræ; anterior surface. Right articular process of upper one is displaced and caught. Partial dislocation. Clinically, see Fig. 1919.

turned to the left and will be bent over to the right, as in Fig. 1922. The sternocleidomastoid will be tense on the left side and lax on the right side. Now suppose, as a second illustration, that there is a dislocation of a right articular process which becomes caught on the top of the articular process

below it and does not slip into the hollow in front. The deformity will be seen as in Fig. 1919. The head will turn to the left as in the complete dis-

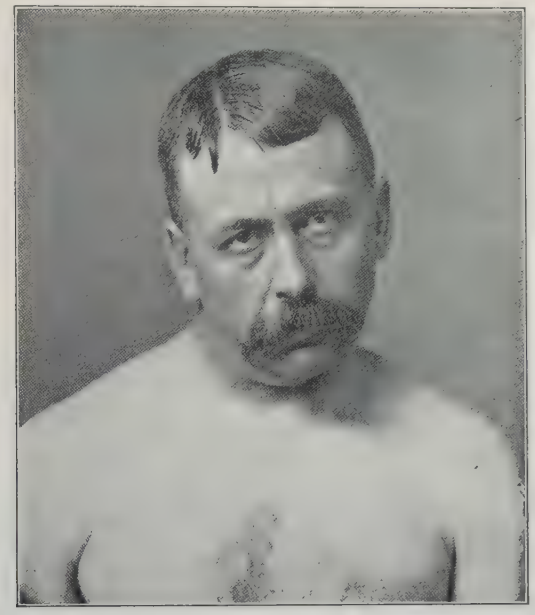


Fig. 1922.—Dislocation of right articular process; ordinary form, in which the process has slipped way over; head is, therefore, to the left and bent to the right; the sternomastoid muscle is tense on the left, lax on the right (Walton).

location, but the head will be bent to the left because the process is caught upon the top of the one below.

Fig. 1923.—Complete unilateral right dislocation. Head rigid. Before operation. Process has slipped way over (Beach, Walton).

This dislocation is often overlooked because of the absence of serious symptoms of paralysis.

Fracture of an articular process may occur together with the displacement. This is fortunately rare.

Fig. 1924.—Unilateral dislocation. After operation. Head perfectly flexible (Beach, Walton).

Fig. 1925.—Partial bilateral cervical dislocation; anterior view. Illustrates positions of bones.

Fig. 1926.—Same as Fig. 1925. Lateral view.

The **treatment** of these cases should be by what Dr. Walton has demonstrated and very properly called retrolateral flexion and rotation without

extension. No amount of extension will unlock the dislocation. The head is to be bent laterally and slightly backward; that is, abducted away from the side displaced. This will raise the articular process out of the notch into which it has fallen. Then rotation of the displaced articular process backward into position will effect a reduction. This, of course, is best done under ether anesthesia. It requires firm, even manipulation, but no very great force.

The cases reported are too few to determine how long after a dislocation has occurred that this procedure will prove efficient. Several cases are on record in which spontaneous reduction has occurred. If untreated, some of these cases recover from the immobility and pain, so that the disability is but slightly noticeable.

Fig. 1927.—Dislocation forward of sixth cervical vertebra. Total paralysis below nipples. Death eighteen hours after the accident (Warren Museum specimen).

Dr. Walton writes as follows: "This diagram (Fig. 1930) shows the upper surface of the lower of the two vertebræ concerned, that is, the one in normal position. The articular processes of this vertebra are marked *x*, *x*. The *left* articular process of the vertebra above having slipped into the intervertebral notch *y*, the situation of its spinous process will be indicated by the dotted lines. The direction in which the head must be tilted for reduction is indicated by the line *z* (in other words, if the patient is facing north the head must be tilted southeast); slight rotation in the direction of the short curved arrow on the right of the diagram may be necessary to free the process. After the articular process is freed, rotation into place in the direction of the long curved arrow on the left of the diagram will complete reduction. In case the *right* articular process has been displaced by the dislocation, these movements should be reversed."

Fig. 1928.—Fracture-dislocation of probably the fifth cervical or the sixth. Photograph taken several months after the accident. No disability save that due to position of head.

Fig. 1929.—Lateral view of Fig. 1928. Head assumed this position immediately after a fall down stairs.

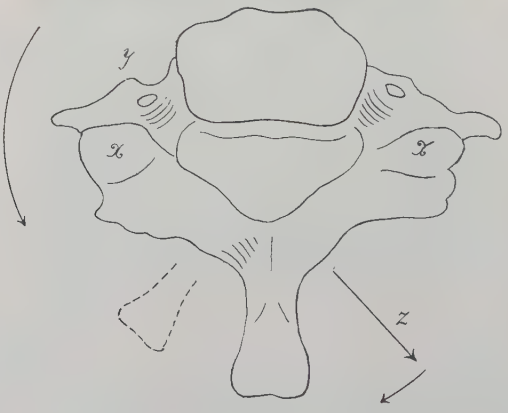


Fig. 1930.—Diagram showing direction of tilting and rotating in reduction (Walton).

In case of bilateral dislocation one process should be freed first, as in unilateral dislocation, then the other. Ryerson and Walton have each been able to satisfactorily reduce by manipulation alone a dislocation six months after its production.

Precautions.—1. The patient should be thoroughly anesthetized. This proceeding alone may produce the desired result.

2. The patient should be placed upon a chair for the operation rather than upon a table, for when the patient is in the sitting posture the operator not only has more freedom of movement, but is also less likely to become confused with regard to the movements of reduction.

3. Extension not only does not help reduction, but, as Walton suggests, may perhaps hinder it by lessening the effectiveness of the fulcrum furnished by the articular processes of the uninjured side. This fulcrum is essential to the elevation of the displaced process on the other side. The head should therefore be *tilted or rocked without traction.*

Taylor's Method of Treating Fracture-dislocation of the Cervical Vertebræ.[1]—It is desirable to relieve the cord at the earliest possible moment of pressure from a displaced vertebra. The lumen of the vertebral foramen is considerable, and the spinal cord is wonderfully protected and slung in the center of this space, but when a displacement of a vertebra occurs with or without fracture the cord, because of the narrowed space and the associated edema and hemorrhage, may be seriously compressed.

A method which will eliminate the bony destruction and the continuing external pressure on the cord without the added risk of an open operation would favor spontaneous recovery in the cord.

The principle consists in controlled traction exerted on the head (with countertraction on the lower extremities) until the spasmodically contracted cervical muscles have relaxed sufficiently to permit reduction by bimanual manipulation on the part of the surgeon.

Fixation is maintained by a plaster-of-Paris jacket surrounding the trunk and neck, holding the neck as much extended as is feasible.

Operation.—The patient is placed supine on a Hawley fracture table, with the trunk from the waist line upward supported on a narrow metal strip padded slightly and ending between the scapulæ.

A leather contrivance used by orthopedists to suspend patients by the head is placed so as to allow traction on the patient's chin and occiput. Through its two suspension rings which lie just above the vertex of the patient's skull a double bight of clothes line is passed, and, continuing around the waist or pelvic girdle of the operator, is tied so as to keep the patient's vertex only a short distance from the operator, who faces the patient and grasps the dislocated neck in the damaged area. Meanwhile, the lower extremities of the patient are bound to the table, or held by strong assistants, to give countertraction. Another assistant may be necessary to keep the patient's body balanced on the narrow metal strip between his scapulæ (Figs. 1931–1933).

[1] Archives of Neurology and Psychiatry, December, 1924.

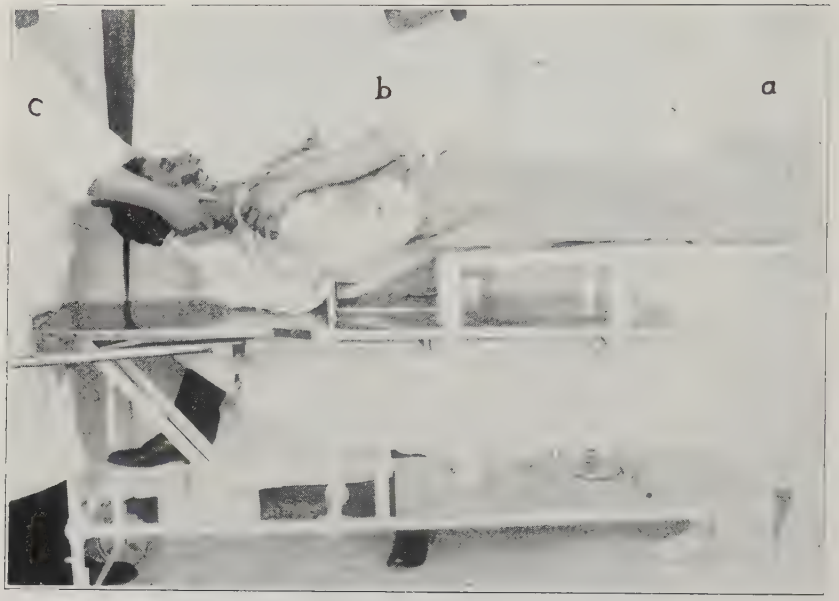


Fig. 1931. Patient on Hawley table. Traction straps arranged on head and chin. Countertraction provided for by two assistants, *b* and *a*. Operator stands at *c*, holding head of patient between parallel wrists as neck is steadied by hands (Taylor).

Fig. 1932.—Note position of hands of operator and of first assistant. Details of the head end of apparatus. Note complete control operator possesses of the position of head and spine (Taylor, Archives of Neurology and Psychiatry, December, 1924).

When everything is ready, the operator applies traction on the neck muscles gradually and increasingly by backing his body away while holding the neck between his two hands, thus maintaining absolute control of the

Fig. 1933.—Detail of head traction straps and their arrangement (Taylor, Archives of Neurology and Psychiatry, December, 1924).

Fig. 1934.—Before reduction. Dislocation of the fifth cervical forward on the sixth cervical vertebra. Note locking of articular processes and that extension at first must be forward to unlock them with minimum force and traction (Taylor).

whole procedure. The traction is at first exerted in the axis of that portion of cervical spine *above* the injury so as to unlock the articular processes of the damaged vertebræ. After traction for a period varying with the strength and degree of spasm of the neck muscles (from five to ten minutes), the neck will be felt to elongate gradually, the bones to unlock, and then the head and upper spine are allowed to sag gently downward while still under traction until reduction is accomplished, the operator's hands assisting by propping the lower segment of the cervical spine and manipulating the upper segment gently with the thumbs, if necessary, to complete the reduction.

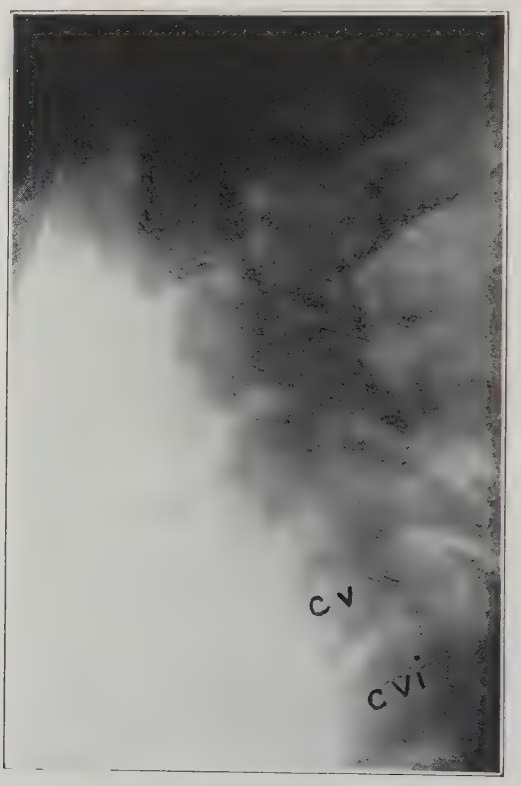


Fig. 1935.—Reduction, first time. Note that intervertebral disk is diminished in thickness and articular processes are not quite seated home (Taylor).

Reduction is indicated: (*a*) sometimes by the patient who feels the bones slide into place, with immediate relief of previous discomforts; (*b*) by finding the spinous processes in proper alignment and spacing; (*c*) by a Roentgen-ray plate taken by a portable machine and developed while the patient is retained on the table.

As soon as the reduction is verified a well-padded plaster-of-Paris jacket (previously described) should be applied while the operator maintains the head and neck in correct position. This jacket should insure moderate extension of the neck between shoulders and occiput and chin, with slight back-

Fig. 1936.—Before reduction. Note extreme forward displacement of the fifth cervical vertebra and locking of articular processes (Taylor).

Fig. 1937.—Taken on the table immediately after reduction, showing complete reduction, see Fig. 1936 (Taylor).

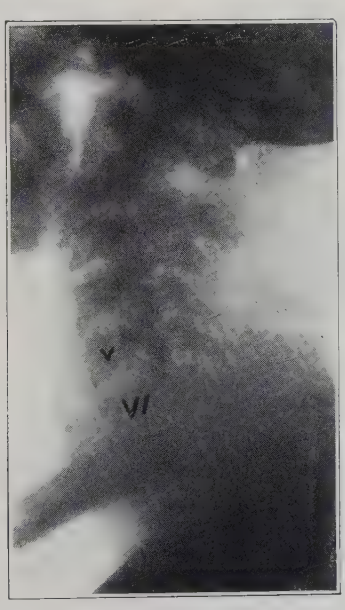


Fig. 1938.—Three days after reduction, showing normal alignment (Taylor).

ward flexion of the head and upper part of the neck to check any tendency to recurrence. This jacket is kept on for many weeks, until the damaged region has had plenty of time for primary repair. It may then be replaced by a leather jacket and neck piece properly reinforced by steel strips. Such

support must be maintained until good bony union has occurred between the damaged vertebræ, which apparently requires about a year.

Taylor has successfully carried out this procedure in 3 cases. I append Taylor's own comments as valuable in this connection.

While 3 cases are, of course, not sufficient to justify any generalizations, the facts brought out suggest several matters worthy of discussion. Discussion will be more to the point if the causes of symptoms, both immediate

Fig. 1939.—Sixteen months after reduction with the use of constant extension apparatus. Note the absorption of the anterior portion of intervertebral disk with tilting forward of upper spine and consequent slight angulation. Note also the well-advanced ossification between the two vertebræ (Taylor).

and remote, are systematically reviewed, and the logical principles of treatment taken up.

Taylor summarizes the immediate and remote effects of a fracture dislocation as follows:

1. The Immediate Results:
   (*a*) Cord: Compression, contusion, laceration, hemorrhage, gross or punctate; rapidly followed by edema. More or less degeneration of cord substance occurs according to severity and duration of factors involved.
   (*b*) Nerves: Compression, laceration, contusion as they pass through the foramina between the vertebræ involved.
   (*c*) Bones and disk: Contusion, laceration, comminution, damaged blood-supply.

2. The Remote Results:
   (*a*) Cord: Transverse pressure myelitis caused by edges of dislocated bones if reduction has not been accomplished.
   Also, more or less degeneration of cord substance according to the degree of "immediate" injury.
   (*b*) Nerves: Delayed regeneration according to persistence of compression by bony deformity, or formation of cicatricial tissue as the result of contusion, laceration, etc.
   (*c*) Bones and disk: Softening, erosion, and absorption resulting from damaged nutrition. If extreme, kyphosis with increasing angulation and compression of the cord will occur.

The fundamental aim of treatment must be to minimize both the immediate and remote results of the injury to the spinal cord and nerves. Obviously, one of the most important steps must be the earliest possible neurological and roentgenographical study followed by reduction of the deformity, with fixation in normal position. This removes *continuing* trauma from the nerve structures. There is still left to be combated the contusion, laceration, and secondary edema of the nerve structures resulting from the primary injury. The dura is a firm, inelastic tube which presents unyielding resistance to the swelling cord, and if this swelling be great enough and sufficiently prolonged, there will be degeneration of the cord much increased over that due merely to the primary impact. For relief of this edema consideration must be given to open operation, which, as far as reduction of deformity is concerned, cannot compare with the simple and efficient method above described.

Allen's experimental work on dogs showed that cords, traumatized beyond recovery under ordinary circumstances, could be salvaged to a considerable degree if the dura were freely opened and the cord itself incised posteriorly in the damaged area to permit easy escape of the edematous fluid. He found that satisfactory results depended on splitting the dura and cord within a comparatively few hours after the injury. It was after the presentation of his work that the patients in the three cases, previously cited, were operated on. It was impossible to operate within the number of hours prescribed, and the disastrous result in each of the cases, and especially the condition of the cord substance as it spurted through the incised dura, led me to believe that the patient's chances were better without open operation. Someone else may, for various reasons, have more success and present sound arguments for operative treatment in selected cases.

Whether the use of hypertonic salt or magnesium sulphate solutions would influence the edema of the cord, and also whether cupping or thermal therapy would have any value, remains to be seen.

In all spinal injuries in which the intervertebral disk is lacerated and contused and the involved vertebral bodies are somewhat crushed, there is serious interference with nutrition of the damaged structures, which causes softening and absorption, varying with the degree of injury, and becoming more and more evident with the lapse of months. In the accompanying roentgenograms this absorption is definitely shown, and it occurred in

spite of the constant use of a support to keep the weight of the head off the damaged vertebræ (Fig. 1939). For this reason, it seems to be of prime importance to keep the support on constantly until solid bony union between the two damaged vertebræ has occurred, so as to minimize the ultimate deformity. This has required about one year in two of the cases. Meanwhile physical therapeutics and muscle training must be systematically used.

Taylor's Summary.— Fracture dislocations of the cervical vertebræ should be reduced as soon as possible after careful examination has determined the condition. The best method at present is by manipulation.

The original technic herein described has the advantages of simplicity, of complete control of the injured structures, of avoidance of additional injury, and of facility in checking up the success of the reduction by means of a roentgenogram.

The patient must wear a support continuously day and night, until solid bony union has occurred between the damaged vertebræ.

Physiotherapy and muscle training must be used to obtain the best results.

The same principles may well apply to fracture-dislocations in lower portions of the spine, and a modification of this technic would assist materially in improving results.

DISLOCATION OF THE JAW

The common dislocation is of the inferior maxilla forward. It is ordinarily a bilateral dislocation. The condyles of the lower jaw slide forward and over the articular eminence of the temporal bone. There is usually no rupture of the capsular ligament.

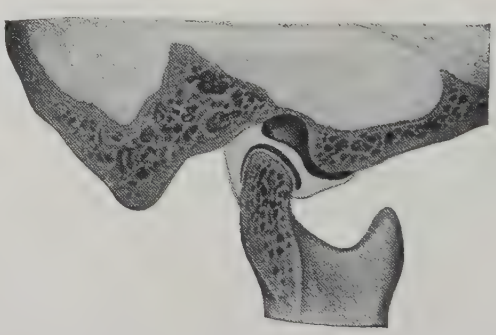


Fig. 1940.—Note the normal relations of the condyle to the glenoid; the interarticular cartilage (after Helferich).

The appearances of such a dislocation are well shown in Figs. 1942 and 1943. The mouth is open; the inferior maxilla is fixed and is forward of its usual place; the masseter and temporal muscles are stretched and taut; the normal hollow of the glenoid cavity can be felt in front of the ear; ordinarily this is filled by the articular process of the lower jaw. If only one side is dislocated, the chin will be pushed over to the opposite side from the dislocation and the signs will be unilateral.

Reduction occasionally occurs spontaneously. In order to effect reduction easily it is necessary to relax the lateral ligament of the joint. The

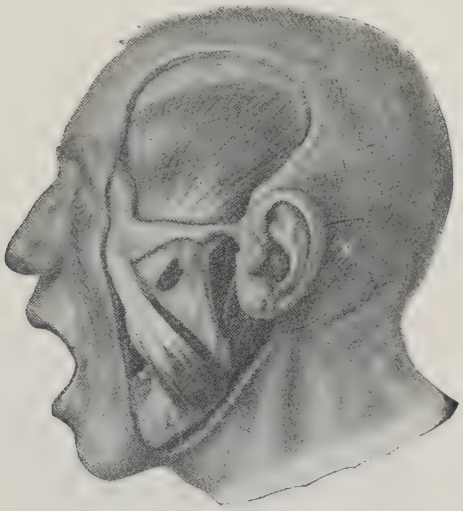


Fig. 1941.—Double dislocation. Note open mouth; displaced articular process; empty glenoid. Capsule uninjured; temporal muscle taut (after Helferich).

maneuver of reduction is best carried out with the aid of general anesthesia. In order to relax the lateral ligament the mouth should be still further opened

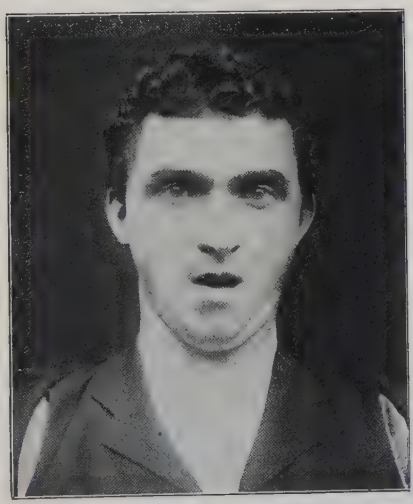


Fig. 1942.—Bilateral anterior dislocation of the lower jaw. Note depressed chin, rigid lower jaw, open mouth, drawn cheeks (Massachusetts General Hospital).

Fig. 1943.—Lateral view, same case as Fig. 1942. Note rigidity of lower jaw muscles. Neck held stiffly (Massachusetts General Hospital).

by pressure upon the incisor teeth; that is, by depressing the chin. Having thus somewhat relaxed the lateral ligament, direct pressure backward will effect a reduction.

The more common and older method used for reducing this dislocation is by pressing down upon the molar teeth and lifting and pressing back the chin. This method is usually not so satisfactory as is that first described.

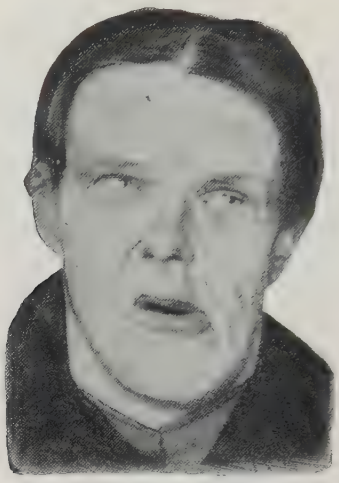


Fig. 1944.—Dislocation of jaw, right side (Perthes).

Recurring dislocations can be successfully treated by open incision and suturing the meniscus to the periosteum of the bone Simple immobiliza-

Fig. 1945.—Fracture of the inferior maxilla mistaken for a unilateral dislocation. Note deviation of the chin to the left side.

tion of a reduced dislocation for a period of a few weeks will often prevent recurrence of the difficulty.

Old irreducible dislocations may require resection of the condyles of the lower jaw, or it may be possible to reduce the dislocation by the method of McGraw. McGraw's method consists in making a tiny incision through the skin over the neck of the inferior maxilla and inserting through it a steel hook, which is usually so bent as to fit accurately the neck of the jaw. Traction upon this hook will sometimes reduce the dislocation.

DISLOCATION OF THE CLAVICLE

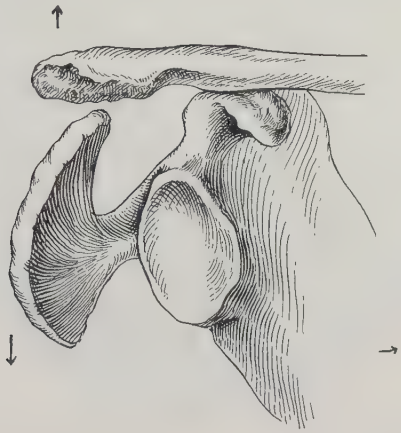


Fig. 1946.—Dislocation of the acromioclavicular joint illustrating the fulcrum action of the coracoid process. The movement taking place in outer end of clavicle, acromion process, and inferior angle of scapula illustrated by the several arrows (after Davis-Peotti).

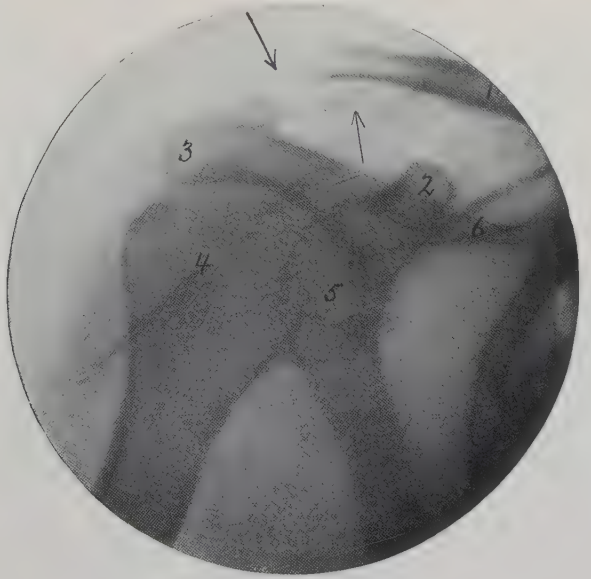


Fig. 1947.—Dislocation of the acromioclavicular joint. *x*-Ray appearance of a case before operation: 1, Clavicle; 2, coracoid process; 3, acromion process; 4, head of humerus; 5, glenoid cavity of the scapula; 6, spine of the scapula. The upper arrow points to the acromioclavicular joint. The lower arrow points to the periosteum stripped off of the under surface of the clavicle.

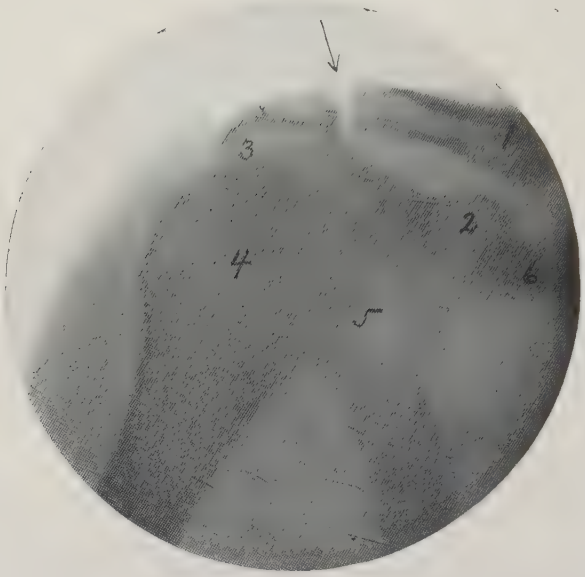


Fig. 1948.—Dislocation of the acromioclavicular joint. *x*-Ray appearances after operation. Same case as the preceding. Explanation of figures same as in previous illustration. Upper arrow points to the now normal relations of the acromioclavicular joint.

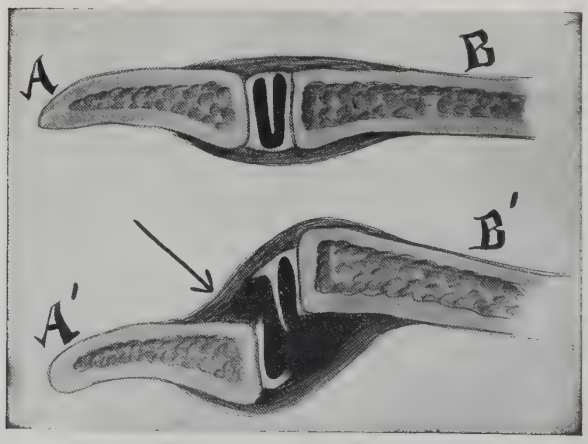


Fig. 1949.—View of the acromioclavicular joint on frontal section from in front: *A–B*, The acromioclavicular joint. Note the superior and inferior ligaments forming the capsular ligament. Note the interarticular fibrocartilage. *A′–B′*, Dislocation of the joint, rupture of interarticular ligament. Note especially the superior ligament stripped off the acromion and the inferior ligament stripped off the clavicle.

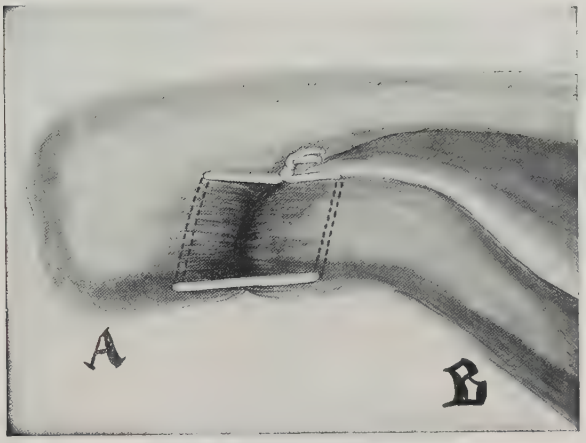


Fig. 1950.—View of the acromioclavicular joint from above. To illustrate a suture passed through transverse drill holes in the acromion *A* and clavicle *B*.

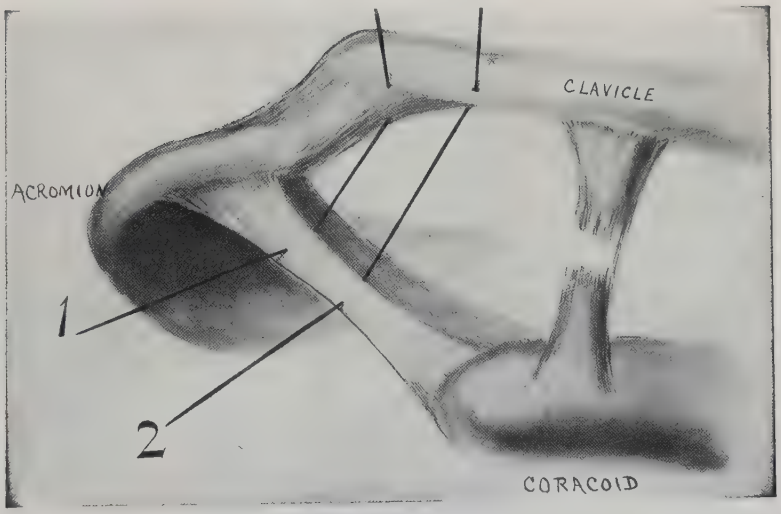


Fig. 1951.—View from in front, looking at the right shoulder. Diagram representing a complete dislocation of the acromioclavicular joint. Note the stretching of the acromioclavicular joint capsule, the torn coracoclavicular ligament. Note the sutures passed through the capsule and clavicle to the coraco-acromial ligament.

Fig. 1952.—Acromioclavicular dislocation. Dislocation of the outer end of left clavicle upward. Complete form. Disability of upper arm, certain movements painful. Treatment of this dislocation is often successful by pressure applied after reduction, as shown under fracture of clavicle. Open incision and suture are indicated if reduction is impossible and disability exists.

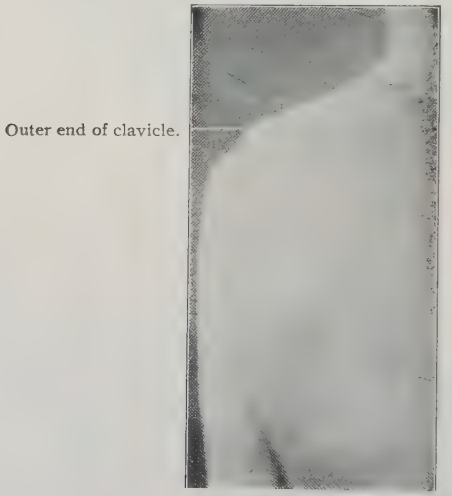


Fig. 1953.—Upward dislocation of the clavicle at the left acromioclavicular joint.

Fig. 1954.—Dislocation of the sternal end of the clavicle upward and forward. The clavicle acting as a lever with the first rib as a fulcrum (after Davis-Peotti).

DISLOCATION OF THE ACROMIOCLAVICULAR JOINT

A dislocation of the acromioclavicular joint usually means that the outer end of the clavicle is displaced upward and slightly outward. This dislocation is not very uncommon. It occasions varying degrees of deformity and certain disabling symptoms may be produced by it. Ordinarily it is a dislocation which is readily treated by pads and simple retentive apparatus. At times, however, it is impossible either to reduce the dislocation completely or to hold it reduced. Occasionally the deformity is so great as to be very noticeable.

It seems probable from the observation and experience of Krecke, Poirier, Rieffel, and Sheldon: (1) that the acromioclavicular ligaments are torn in all cases; (2) that the conoid ligament is sometimes torn in incomplete dislocations; (3) that the conoid ligament is always torn in complete cases; (4) that the conoid and trapezoid ligaments are usually torn in the complete cases.

A male, aged twenty-four (see *x*-rays, Figs. 1947–1951), after having had a fall from a ladder in the gymnasium, presented a dislocation of the left acromioclavicular joint. The dislocation persisted despite the usual treatment with pads, adhesive plaster, and bandages. The dislocation was only partially reducible. The deformity was marked. There was about $\frac{3}{4}$ inch separation between the clavicle and the acromion; that is, between the articular surfaces. There was no especial loss of function.

Operation was sought because of the deformity. About six weeks after the accident a suture of the acromioclavicular joint was made. The material used was linen and catgut. The patient was kept in bed on his back for ten days following the operation. The result was perfect. There remained no deformity and the movement and usefulness of the joint were restored.

The indications for operative interference are irreducibility and a failure to maintain reduction. The dislocation is irreducible because of the interposition of the torn capsule or of the ruptured trapezius muscle. *The maintenance of reduction is impossible because of the rupture of the coracoclavicular ligaments.* At operation, therefore, the indications are to remove any interposed parts and so to suture the torn ligaments as to restore the relation of the parts to their normal condition.

I would formulate the treatment of a specific case somewhat as follows: If the dislocation is one of moderate degree, it should be treated by simple retentive apparatus. If the dislocation is extreme, in which case it is probable that the coracoclavicular ligaments are torn, a suture of the parts is indicated. If the retentive apparatus does not hold cases of the first class, then suture should be employed.

Various methods of suture have been used: by wire, by silk, and by absorbable material. Different forms of pin have been employed. The method of placing the suture seems to be of some importance.

In order to secure a firm hold on the outer end of the clavicle a suture should be placed so as to make traction on the clavicle from below in the

direction of the coraco-acromial ligament. The suture should be passed through the clavicle and the coraco-acromial ligament.

Fig. 1955.—Dislocation of the inner end of the clavicle. Note the arrow points to the left sternoclavicular joint. Note the tense left sternocleidomastoid muscle.

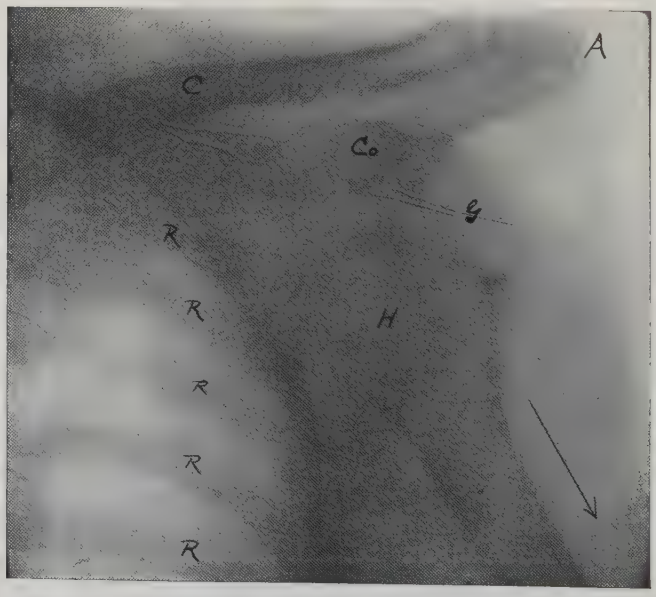


Fig. 1956.—Subcoracoid dislocation of the humerus: *H*, Head of humerus; *G*, glenoid; *Co*, coracoid; *C*, clavicle; *A*, acromion; *R*, ribs. Note the position of the head of the humerus with relation to the glenoid cavity. Note the axis of the humerus.

The treatment of this dislocation with the patient on the back, whether with or without operation, will, of course, remove the weight of the upper extremity and so assist very materially in the proper healing of the parts.

Dislocation of the Inner End of the Clavicle.—Occasionally this dislocation will require suture. A. W. Allen has successfully sutured the clavicle to the second rib. Drill holes passed through the clavicle and rib allow of introducing strips of fascia lata 1 inch wide, tied and fastened securely.

DISLOCATION OF THE SHOULDER

The head of the humerus, through extreme abduction of the arm, leaves the capsule of the shoulder-joint at its lowest point. The upper end of the humerus rests beneath the coracoid process in the common form of dislocation of the shoulder.

The signs of a subcoracoid dislocation are partly illustrated in the chapter on Fracture of Humerus. The direction of the long axis of the upper arm is

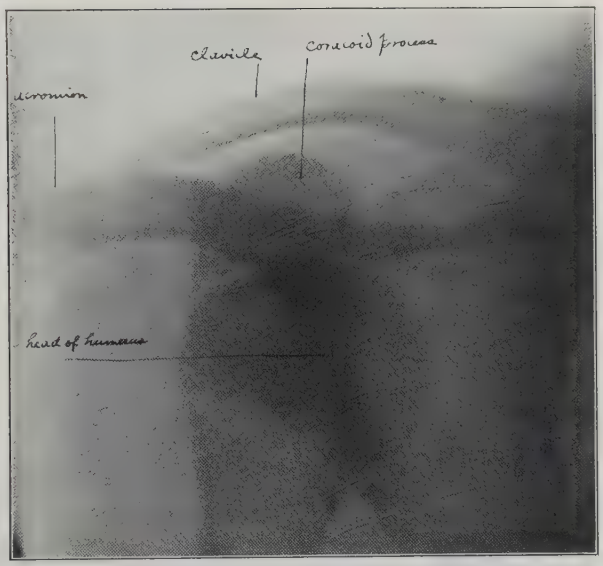


Fig. 1957.—*x*-Ray of a subcoracoid dislocation of the humerus. Note the position of the humeral head, with reference to acromion, coracoid, clavicle, and glenoid cavity. (*x*-Ray taken by Mr. Dodd, Massachusetts General Hospital.)

changed from the normal. The arm is permanently abducted from the body. Voluntary movements of the shoulder are more or less restricted. The shoulder is flattened because the head of the humerus is absent from its normal position. The head of the bone is felt in its new position under the coracoid process. The head of the bone may be fairly easily felt by palpating the axilla. The elbow cannot be brought readily to the side.

Before any attempt is made at reducing the dislocation it is wise to determine so far as possible, by careful examination and by the assistance of the *x*-ray, whether or not a fracture of the anatomic or surgical neck or the tuberosity of the humerus or of the glenoid cavity of the scapula has occurred, complicating the dislocation. Obviously, if a fracture exists associated with

a dislocation, it will most likely be impossible to effect the reduction by manipulation.

Fig. 1958.—Subcoracoid dislocation of the left shoulder. Note change in axis of humerus. Note method of palpating under acromion, demonstrating hollow on the left due to absence of head of bone from the glenoid cavity.

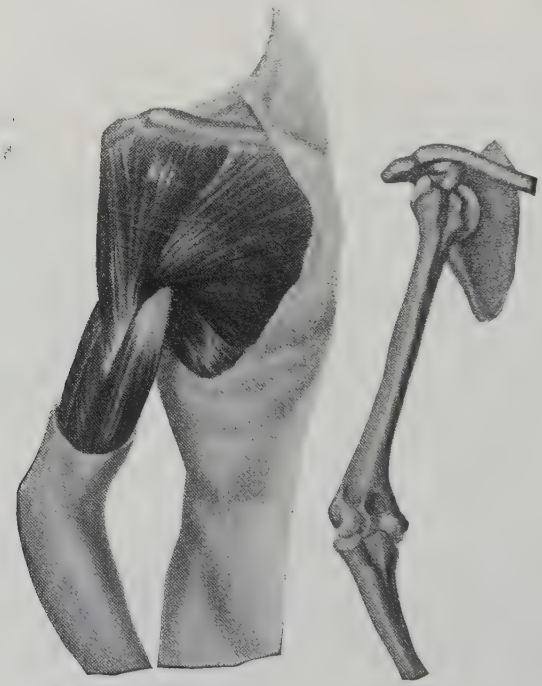


Fig. 1959.—Dislocation of the humerus. Note muscles of shoulder, flattened deltoid. Note position of the head of the humerus (after Helferich).

The older method of reduction is still often useful. By the older method traction is made upon the humerus, which is grasped at the elbow, with the arm raised to a right angle with the body. Countertraction is made by steadying the trunk by means of a folded sheet around the chest. While

traction is being made the arm is gradually brought to the side. A third assistant manipulates by pressure the head of the bone while the traction is being made.

The best method for the reduction of the common subcoracoid shoulder dislocation is that known as Kocher's method. It consists of the following procedures:

1. With the patient lying upon the back, the surgeon, standing upon the side of the dislocated shoulder, grasps with one hand the dislocated humerus

Fig. 1960.—Reduction of subcoracoid dislocation of the shoulder. *First position* (see Fig. 1961): *Elbow at side, forearm rotated outward.* Note fulness (head of humerus) beneath coracoid process (*m*); absence of head of humerus under acromion (*l*); relaxed muscles (*g*, *h*, *j*); *a*, deltoid; *b*, pectoralis major; *c*, pectoralis minor; *d*, coracobrachialis; *e*, biceps, two heads; *f*, triceps; *g*, supraspinatus; *h*, infraspinatus; *j*, subscapularis; *i*, humerus; *l*, acromion process; *m*, coracoid process; *n*, coraco-acromial ligament.

above the condyles, and with the other hand the wrist of the patient. The forearm of the patient is flexed at a right angle. The elbow is carried well to the side of the body (Figs. 1960, 1961).

2. See Figs. 1962 and 1963. The humerus is rotated upon its long axis, carrying the forearm outward, external rotation. This movement is an important one, as by it the opening in the capsule through which the head of the bone left the joint is relaxed and made patent.

Fig. 1961.—Reducing dislocation of the shoulder. Note shoulder over edge of table; patient on back. *First step:* Elbow at side. Note method of grasping above elbow and wrist.

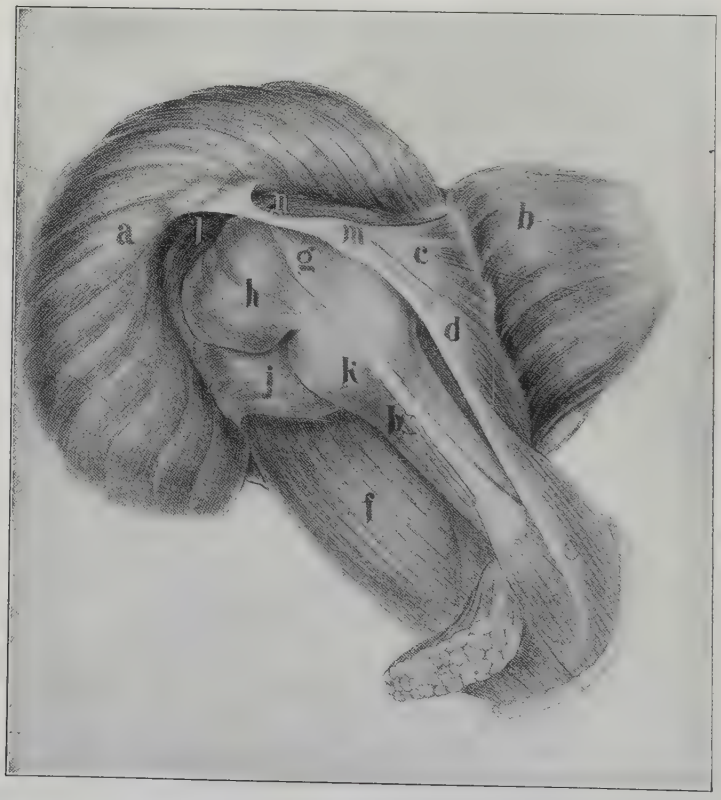


Fig. 1962.—Reduction of subcoracoid dislocation of the shoulder. *Second position* (see Fig. 1963): Forearm held rotated outward. *Elbow advanced across the thorax* to near median line. Traction downward in line of long axis of humerus. (Lettering same as in Fig. 1960.)

3. See Figs. 1964 and 1965. With the humerus thus rotated strongly outward, the elbow is strongly adducted just across the median line of the body.

Fig. 1963.—*Second step:* Elbow at side. Rotation of forearm outward to the extreme limit of rotation.

Fig. 1964.—Reduction of subcoracoid dislocation of the humerus. *Third position* (see Fig. 1965): Elbow held at midpoint of thorax, traction downward on humerus maintained. *Rotation of humerus being made upon its long axis* by carrying hand to shoulder. Note reduction of the dislocation. The head lies under the acromion (*l*) within the capsule of the shoulder-joint upon the glenoid cavity of the scapula. (Lettering same as in Fig. 1960.)

4. See Figs. 1966 and 1967. When the elbow is brought well to the median line in adduction, the hand is placed upon the opposite shoulder, thus rotating the humerus inward.

Throughout these four procedures good steady traction is maintained by the surgeon, downward in the direction of the long axsis of the humerus. This method of Kocher may be used without ether, or with the aid of an anesthetic. In the great majority of dislocations this method will prove efficient.

Recurrent Dislocations of the Shoulder.—These, if frequent and troublesome, may be prevented by incision and by taking a tuck, by means of suture, in the capsule. The anterior incision in the sulcus, between the del-

Fig. 1965.—*Third step:* While external rotation is maintained traction downward is made and at the same time the elbow is carried in adduction to the midline of body.

toid and pectoralis major muscles, is the better method of approach to the joint capsule.

Old Unreduced Dislocations.—It is not known what the limit of time may be within which it is wise and proper to undertake the reduction of an old unreduced dislocation uncomplicated by any fracture. Each individual case must be judged upon its own merits. Suffice it to say that several weeks may have elapsed and yet a dislocation may be reduced by manipulation. The dangers of attempting reduction after several weeks are injury to important vessels and nerves and fracture of the humerus.

When moderate manipulation has been undertaken and failed, operation is indicated. If there is no fracture of the upper end of the humerus

associated with the dislocation, it may be possible, by the assistance of the Porter and McBurney hook, to effect a reduction through an open incision. Usually, when a fracture is associated with a dislocation, and manipulation and operation with the aid of the hook are of no avail, an excision of the head of the bone becomes necessary. This operation is attended with some risk, and yet useful arms are secured by this means.

The treatment after reduction of simple dislocations of the shoulder is important. After having reduced a dislocation it is necessary to partially immobilize the shoulder-joint. This can best be accomplished by a swathe about the body, enclosing the upper arm, and a cravat sling around the neck and wrist. The body swathe may be used only at night. During the daytime the arm may wear the sleeves of shirt and coat and the wrist be supported by a simple cravat sling. Ordinarily it is customary to immobilize the reduced shoulder for many weeks without giving it any passive motion. It is my experience that poor results follow such treatment. It is far wiser and safer to make gentle passive motion upon the first day after the reduction and to continue these gentle movements with increasing force and exertion each succeeding day, until at the end of a week or a week and a half the patient is no longer restrained in his movements, but is encouraged to make all movements that are natural.

UNREDUCED DISLOCATIONS OF THE SHOULDER

Causes of Irreducibility.—A fracture of the anatomic or surgical neck of the humerus; a fracture of the greater tuberosity, which may lie in the joint; the long biceps' tendon may be displaced either so as to hold the head of the bone from returning to the glenoid, or the tendon may slip between the head and the glenoid; the capsule may be stretched over and be adherent to the glenoid cavity; the capsule may become ossified; the glenoid may become filled up with new fibrous tissue or bone; a fracture of the glenoid cavity of the scapula. Any or several of these causes of irreducibility may be present in a given case. An *x*-ray may immediately determine the difficulty.

If the *x*-ray discloses an insurmountable obstacle to reduction, manipulative attempts should be discontinued at once, for only harm can result to already damaged tissues. In the absence of fracture of the humerus or glenoid (conditions which the *x*-ray will reveal) bloodless or non-operative measures should be carefully tried to reduce the dislocated head.

Method of Attempting Reduction of an Old Dislocation of the Shoulder.—Complete anesthesia is necessary. The patient should be placed with the injured shoulder close to the edge of the table. The adhesions (periarticular) should be gently and progressively broken by attempting to perform all the normal movements of the shoulder-joint in sequence (forward and backward swing, abduction, adduction rotation, circumduction). Having broken all adhesions, an attempt by a familiar method should be made to reduce the dislocated head.

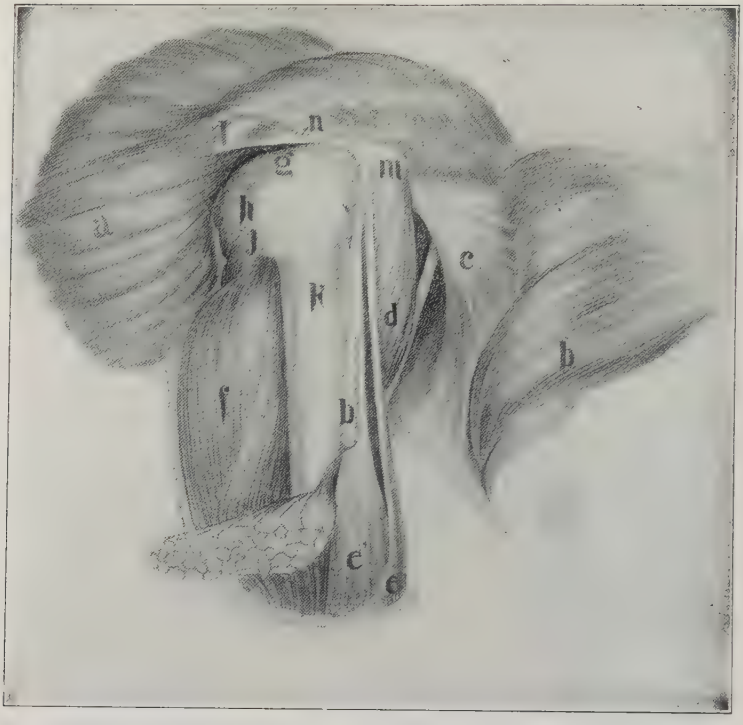


Fig. 1966.—Reduction of subcoracoid dislocation of the humerus completed. *Fourth position* (see Fig. 1967). Note head of bone under the acromion (*l*) to the outer side of coracoid process (*m*) and undisturbed normal anatomical relations. (Lettering same as in Fig. 1960.)

Fig. 1967.—*Fourth step:* While traction is being made rotation inward is made of the arm by placing hand upon opposite shoulder.

Before deciding to operate in a given case the question must be settled as to whether the disability without operation is any greater, in the absence of pain and pressure symptoms, than the disability following operation.

The whole case must be considered from the point of view of the individual's age, sex, health, occupation, temperament, etc. Certain cases after operation have so great a limitation of motion that the arm is of little use. Certain other cases without any operation have fairly useful arms. Each individual case must be decided upon its merits.

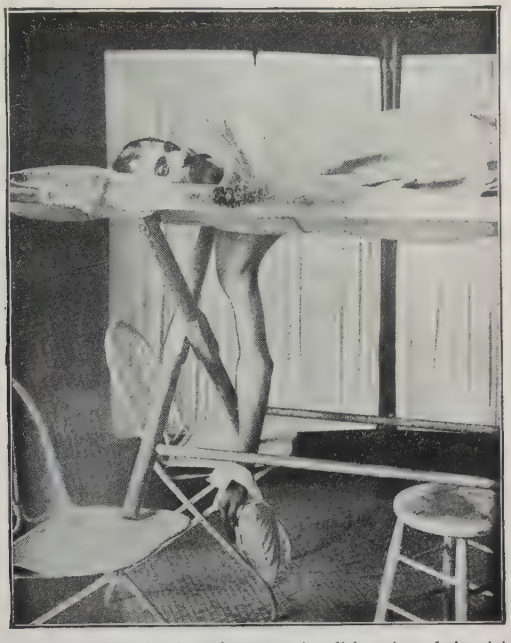


Fig. 1968.—Stimson's method of reduction of an anterior dislocation of the right shoulder-joint. Note patient on right side. Hand and arm hanging through a slit in canvas stretcher at right angles to the long axis of the body. Note weight attached to right wrist. The assumption of this position usually results in the head of the humerus slipping into place without the use of an anesthetic (Stimson).

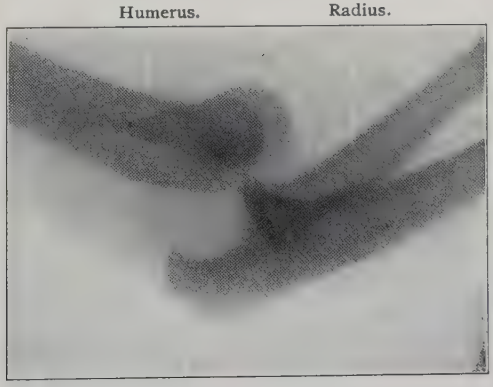


Fig. 1969.—Dislocation of both of the bones of the forearm backward (*x*-ray, Massachusetts General Hospital).

Operative Procedures for Irreducible Dislocation of the Humeral Head.—1. *If no fracture exists:* (*a*) Exposure of the joint, removal of adventitious

tissues, reduction of the head by traction or pressure. (*b*) Removal of a portion of the head of the bone, placing upper end of shaft near glenoid. (*c*) Complete excision of the head of the bone.

2. *If a fracture exists:* (*a*) An attempt should be made to replace the head in the glenoid cavity and then to unite the fractured bone fragments. If this is impossible, then (*b*) an excision of the proximal fragment should be done. If there are reasons why it is wise to postpone operation in an acute case, resection may be later considered, if pain and too great disability supervene, and demand a secondary operation. One should not operate in those old and enfeebled individuals debilitated in all their tissues. The anterior incision, approaching the capsule through the interspace between the deltoid and pectoralis major muscles, is the most satisfactory of all the incisions.

End-results After Excision of the Shoulder for Dislocation Fracture.—After excising the head of the humerus rotation at the shoulder will be

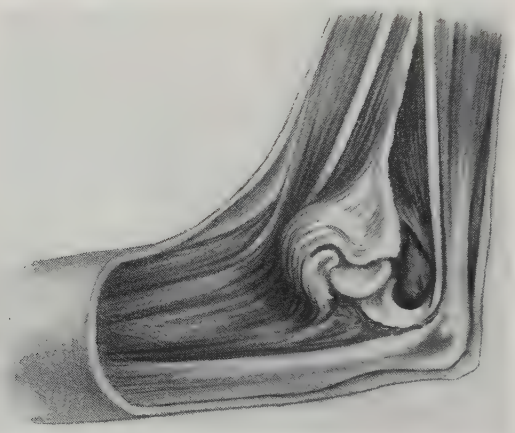


Fig. 1970.—A diagrammatic drawing of a posterior dislocation of the elbow, inner view. Note the trochlear of the humerus and ulna and the ulnar nerve. Note the tense triceps tendon (after Davis and dissections).

impaired and abduction will be much lessened. Forward and backward swing will be nearly normal, adduction will be normal. The power of the forearm will be maintained. The disability following excision is very largely due to inability to abduct the arm from the side. It is often impossible to touch unaided the top of the head with the hand of the operated side. The atrophy of the whole group of shoulder muscles is marked.

Subluxation of the Head of the Radius.—This occurs only in young children of about two or four years old.

The *cause* of the subluxation is the pulling suddenly on the extended arm with considerable force. This happens when a child falls and is kept from falling far by the jerk up of the one holding the child's hand. The head of the radius is pulled away from the capitellum.

Symptoms.—The child feels instant pain and cries because of it. The forearm is permanently pronated. The arm is not used. Tenderness of

the radial head region is present. It is impossible to supinate the forearm.

Treatment.—Reduction of the subluxation may be spontaneous. While the elbow is being examined the symptoms may disappear. Pressure on the radial head when the arm is flexed and simultaneously strongly supinated will reduce the subluxation. The surgeon will feel a distinct slip or sharp click as reduction occurs. The arm should be held at a right angle in a sling for several days.

DISLOCATION OF THE ELBOW

The usual form of displacement is of both bones of the forearm backward. The normal relation of the three bony points of the elbow is not maintained (see Elbow Fractures). The olecranon is felt to be posterior to

Fig. 1971.—Showing a method of reduction of a dislocation of the elbow backward. Note partial extension of forearm on arm; position of thumbs of surgeon behind olecranon making pressure forward while fingers make pressure backward.

the two condyles. There is a shortening of the forearm. Lateral mobility at the elbow exists. The forearm is held at an obtuse angle. There may be great swelling of the elbow if the injury is seen several hours after the accident. This swelling will obscure the bony relations. Motion at the elbow-joint is limited and painful.

There may be associated with a simple dislocation of the elbow a fracture of the olecranon, of either condyle of the humerus, or a fracture of the coronoid process. If there is any doubt as to the diagnosis, ether should be administered to facilitate examination. As Stimson has so well insisted, in the reduction of any dislocation the dislocated bone should be reduced by

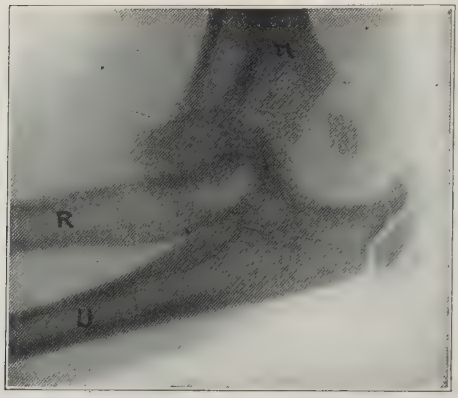


Fig. 1972.—Dislocation of both radius and ulna backward. Note the olecranon epiphysis.

Fig. 1973.—Dislocation of the radius. Note the position of the radial head and the external condyle.

Fig. 1974.—Dislocation of the radial head. Note the relative position of the radial head and the coronoid of the ulna. A rupture of the superior radio-ulnar ligament must have occurred.

the same path along which it came when dislocated. A haphazard method of reduction of a dislocation is unsurgical.

The best method of reducing a dislocation of the forearm backward, when uncomplicated, is by two steps: first, by completely extending the forearm, thus freeing the coronoid from the olecranon fossa and the posterior surface of the humerus; and, second, by direct traction and then flexing. Reduction is best accomplished by the aid of an anesthetic.

Holding the arm extended and pressing with the two thumbs upon the olecranon process, while the lower end of the humerus anteriorly is grasped

Fig. 1975.—Old dislocation of the head of the radius outward and backward. Functional usefulness of the elbow unimpaired. Pronation and supination normal. In such a dislocation were there present any serious disability excision of the head of the radius would be indicated (Codman).

by the fingers of both hands in counterpressure, accomplishes, of course, the same end as that accomplished by the above procedure, and is in many cases simple and efficient (Fig. 1971).

When there is any lateral deformity the bones should be forced into line before attempting to reduce the backward dislocation.

Fig. 1976.—Same case as Fig. 1975. Appearance of elbows in flexion with hands at side of neck (Codman).

The after-treatment of an uncomplicated dislocation of the elbow is by immobilization of the elbow, with the forearm at a right angle with the upper arm. A bandage, with equable pressure, and a sling to the forearm should be applied.

If a recurrence of the dislocation occurs and it is with difficulty held reduced in the right-angle position, the forarm should be flexed to an acute

angle after the reduction. The angle of flexion may be made smaller as the swelling subsides.

Massage and passive motion should be used at as early a date as the second day. This should be painless and should be tentatively employed.

Good functional results are to be expected from uncomplicated dislocations of the elbow occurring in young adults, which are reduced soon after the injury.

UNREDUCED DISLOCATIONS OF THE ELBOW

Reduction of a dislocated elbow becomes after a very few weeks impossible. The disability occasioned by the unreduced dislocation is serious in most instances. Pain, deformity, and ankylosis more or less complete exist.

The chief *obstacle to reduction* of the dislocation is the new bone formed by the stripped up periosteum in the neighborhood of the joint. Fibrous tissue forming over the joint surfaces helps to make reduction difficult and

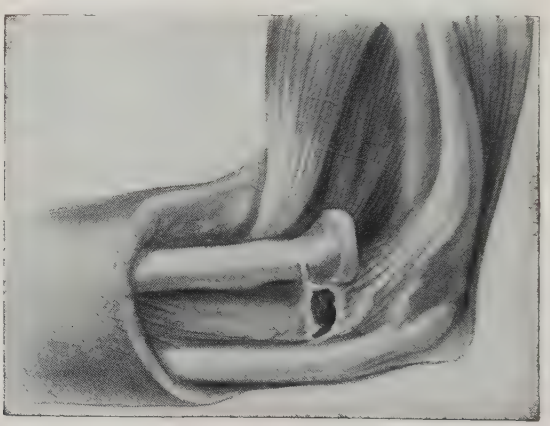


Fig. 1977.—Dislocation of the radial head forward. Note the pull of the biceps; the brachialis anticus beyond the head of the radius; the torn orbicular ligament (after Davis and dissections).

maintenance of reduction almost impossible. Certain fractures occurring at the time of the dislocation may offer additional difficulties to reduction. Prolonged and violent efforts at reduction are extremely unwise and usually futile.

Operation is wise in these cases. That method is the best which exposes all parts of the elbow-joint with the least trauma. Through this incision all intra-articular new bone and all adventitious fibrous tissue are to be removed, the dislocated bones replaced, and the joint closed. Kocher's external lateral incision, as if for excision of the elbow, affords easy access to the joint. Division of the olecranon (Trendelenburg) may facilitate the procedure at times. Two lateral incisions will occasionally be found serviceable. Having removed all adventitious joint tissue and reduced the dislocation, if the articular surfaces are found damaged and there are losses of substance in the articular cartilages, it may be wise to do an arthroplasty upon the joint.

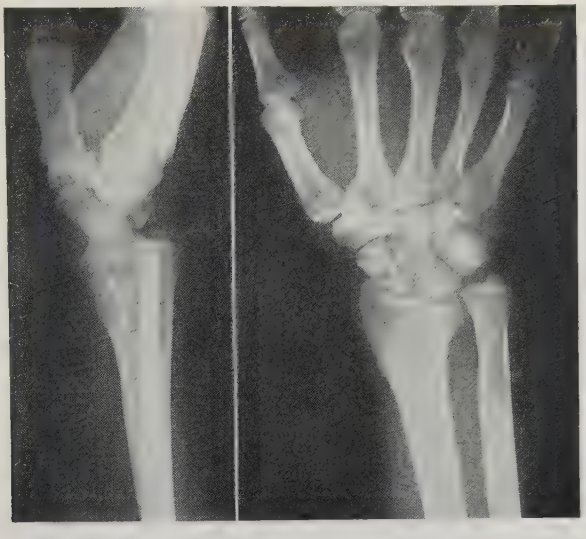


Fig. 1978.—Roentgenograms of dislocation of the ulna (Shortele-George).

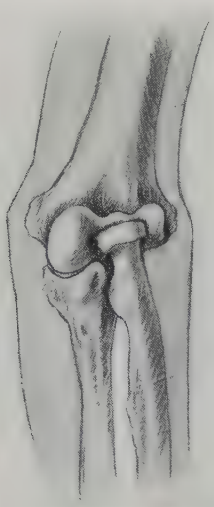


Fig. 1979.—Dislocation of the head of the radius anteriorly, inward and upward (after Davis-Peotti).

Fig. 1980.—Lateral view. Dislocation of the head of the radius forward (after Davis-Peotti).

An arthroplasty is best done upon the elbow by placing within the joint a fat-fascial flap from the posterior surface of the upper arm. The damaged bony articular surfaces are then separated from each other by what subsequently assumes the function of a new synovial membrane.

The results of operation upon old unreduced dislocations of the elbow are satisfactory functionally.

Dislocation of the Carpal Semilunar Bone.[1]—Injuries to the wrist are common. Dislocation of the semilunar bone is relatively unusual. An unseen and suspected tear of ligaments is less likely to be associated with an injured wrist than is a bony lesion. This injury to the semilunar bone is one additional well-defined wrist lesion which, if overlooked, will lead to permanent disability.

Anatomy.—The capsular ligament extends all about the wrist from the base of the radius and styloid of the ulna down as far as the level of the

Fig. 1981.—Normal hyperextension of both wrists. Note the open unprotected position of the semilunar bones (John D. Adams).

metacarpal bones. A thickening in the capsule on the anterior, posterior, external, and internal surfaces forms these strong ligaments.

The anterior ligament is strong, the posterior ligament is weak. This latter fact is significant.

Within this wrist capsule are three main articulations: the radiocarpal, the intracarpal, and the carpometacarpal.

The *movements of the wrist* are such and the contour of bone is such (the overhanging posterior ridge of the lower end of the radius) that limitation of palmar and dorsiflexion is due to some mechanical alteration of the normal relationship of the carpal bones and the base of the radius.

[1] From Papers by J. D. Adams (Journal of Bone and Joint Surgery, July, 1925) and G. G. Davis.

The scaphoid, semilunar, and cuneiform bones form a meniscus subdividing the radiocarpal joint from the metacarpocarpal joint. No muscles are attached to any of these bones of the meniscus. They float. These bones never move directly, but change their position under pressure of the distal row, which is pulled against it by the muscles moving them (Piersol).

Movement at Wrist.—The carpal bones move about an axis transverse, passing through the meniscus bones, in flexion and extension. Dorsal extension is limited by the impact of carpus on the end of radius.

The semilunar occupies a key position in the movements of the wrist. It is, therefore, an important bone.

Causation.—Violent dorsiflexion of the wrist is the immediate force causing this injury.

Ligaments do not tear independently of bony prominences, being fractured or bits of bone avulsed with the ligamentous attachment.

Mechanism of Formed Dislocation of the Semilunar.—Dorsiflexion forced hard causes the posterior horn if the semilunar to ride forward on the artic-

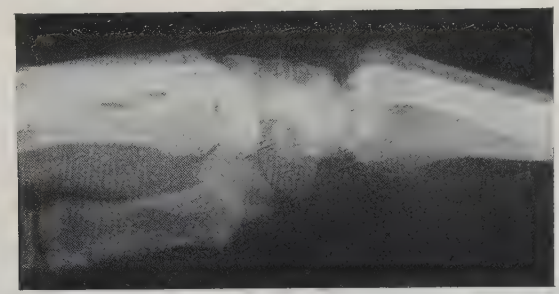


Fig. 1982.—A dislocation of the semilunar bone forward, Type A. This lateral view shows the holding of the os magnum displaced posteriorly permanently, even though the semilunar has been removed. So much time elapsed previously to operation after the accident that despite the removal of the semilunar there is limitation of movement and disability dependent on the permanently displaced os magnum (J. D. Adams).

ular surface of the adjoining os magnum, the weak posterior ligament ruptures, the posterior horn passes to the front of the os magnum (see Fig. 1985). This is the semilunar os magnum displacement.

If the traumatizing force is great enough and continues to act long enough the semilunar will be forced completely out of all its articular relationships to the anterior surface of the wrist (see Fig. 1982). The displacement of the semilunar is always anterior.

When the semilunar dislocation is partial the os magnum is lifted posteriorly in the plane of the wrist toward the dorsum (see Fig. 1985).

J. D. Adams *classifies* semilunar displacements in accordance with the above description into:

Type A—The semilunar os magnum displacement (Fig. 1985).

Type B—The true anterior complete dislocation (Fig. 1982).

Type C—The posterior midcarpal os magnum dislocation (Fig. 1985).

Diagnosis.—The exact diagnosis can be made by the Roentgen ray. Stereoscopic plates are best. All injuries to the wrist should be examined

by the Roentgen ray. No injury whose symptoms persist should be regarded as a sprain.

Fig. 1983.—Operative removal of semilunar bone. *Flexion of wrist.* Note on left absence of semilunar and the prominent os magnum partly occupying position of removed semilunar. Note on right normal wrist-joint in flexion for comparison (J. D. Adams).

1. *Reduction of Dislocation.—Treatment.*—Recent cases coming to the surgeon within two or three days may be reduced by a general anesthetic and manipulation.

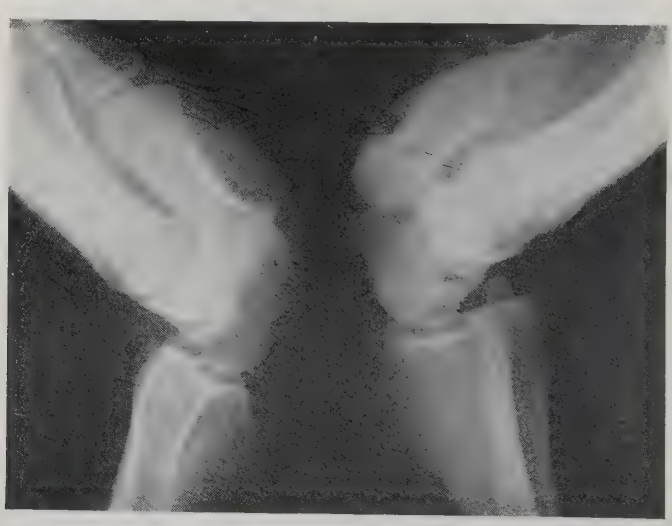


Fig. 1984.—Operative removal of semilunar bone. *Extension of wrist.* Note on left os magnum dropped back to radius level. Note on right semilunar bone *in situ* in normal relation to radius in normal wrist in extension (J. D. Adams).

Strong hand traction and countertraction on the arm combined with forced dorsiflexion and counterpressure over the displaced bone on the palmar surface of the wrist and forcible flexion of the wrist will effect reduction.

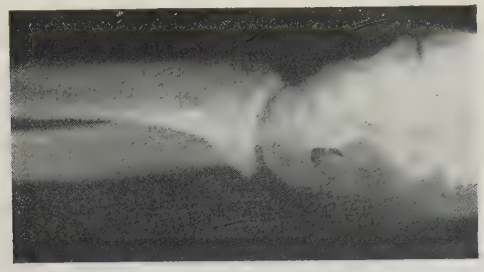


Fig. 1985.—Type A dislocation of the semilunar bone. A semilunar os magnum dislocation. Note the posterior horn of the semilunar engaged against the os magnum holding it backwardly displaced If this dislocation is either reduced early without operation or if the semilunar is removed early by operation, the os magnum will come forward and flexion and extension will be unlimited (J. D. Adams).

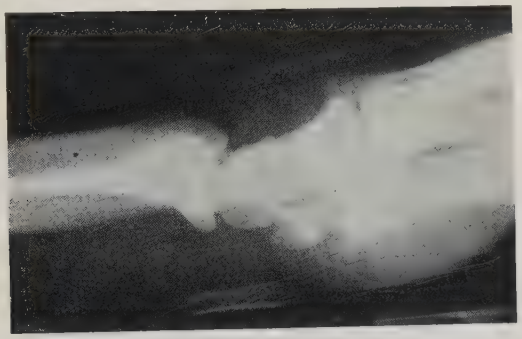


Fig. 1986.—Type A dislocation of semilunar bone; same case as Fig. 1985 after reduction. Note the normal position of semilunar and os magnum. Note hollow at back of slightly extended wrist (J. D. Adams).

Fig. 1987.—Roentgenogram of wrist. Lateral view. Class B. Complete anterior displacement of semilunar bone. The anterior ligament is still attached to the anterior horn of the semilunar (Adams, George, Leonard).

Fig. 1988.—Roentgenogram of wrist. Same as Fig. 1987. Anterior posterior view. Note 1, the overlap of the os magnum and scaphoid. Note 2, semilunar. Note 3, part of os magnum slumped, displaced backward into the position originally and normally occupied by the semilunar (J. D. Adams).

When the dislocation is recognized early, reduction manipulation may be facilitated by the "broom-stick" maneuver (see Fig. 1989).

The hand is placed in extreme extension, the backward pressure made on the semilunar and flexion of the wrist, together with traction on the hand. The backward pressure is graduated well by using a bit of broom-stick handle pressed against the semilunar bone (see diagram) (see Fig. 1989).

When this method fails, operative reduction may be tried by the Davis method (see Figs. 1990, 1991).

In the open operation by an incision over the dorsum of the wrist there is little space between the articular surface of the radius and the os

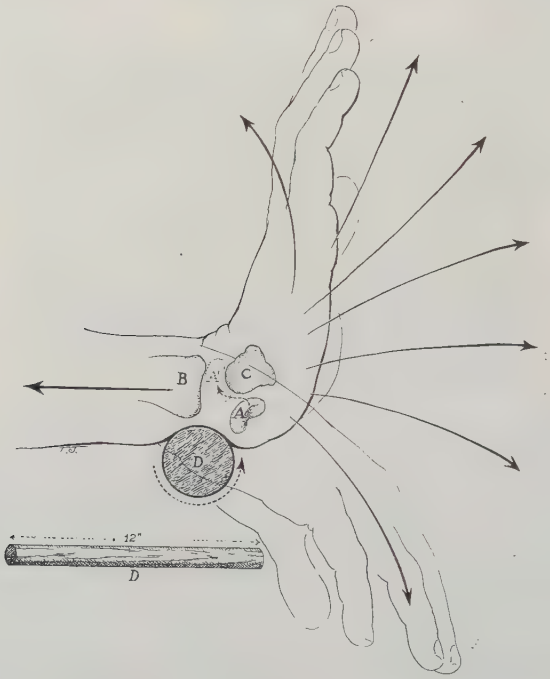


Fig. 1989.—Diagram of the various forces applied in the reduction of the dislocated semilunar bone by the "D broom-stick end method." The arrows indicate the direction of the various forces applied (G. G. Davis, Surg., Gyn., and Obstet., August, 1923).

magnum in which to work. With flexion of the wrist and traction on the hand this space is increased, but not enough for ready reduction of the semilunar bone. Davis has devised a "skid" (see Fig. 1990). The skid is thin enough, curved on the flat, to slide between the closely approximated bones (see Fig. 1991).

Davis finds, as do others—Conwell, Phemister, Hays, Willis—who have used the skid, that reduction can be accomplished without injury to the bones.

Caution.—There is great danger of damaging the flexor tendon sheaths by too great pressure over the displaced bone. The "broom-stick" method, using a surface harder than the thumbs to press on the displaced bone, must be used with care. Moreover, if force, such as can be applied as described

above, will not reduce the dislocation, attempts at closed reduction should be abandoned.

2. *Open Reduction.*—This procedure has not usually been followed by satisfactory functional results if the dislocation has existed some weeks. It is possible to reduce the bone by operation, but, as Adams points out, the

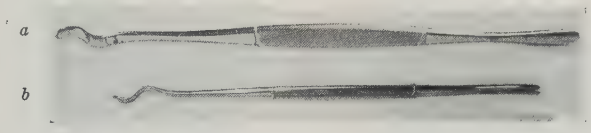


Fig. 1990.—*a*, "Skid" used in reduction of a dislocated semilunar bone. View from above and the side. The instrument is 8 inches in length and tapers from ½ inch in width at the middle to ¼ inch at the end, and varies in thickness from $\frac{3}{16}$ inch at the middle to $\frac{1}{8}$ inch at the tip. It has an S-shaped curve at the end. The distal curve, ¼ inch in length, a large arc of a small circle, is to receive the tip of the semilunar bone; the proximal curve, ½ inch in length, a small arc of a large circle, is to receive the os magnum.

b, Lateral view of "skid" showing the two parts of the S-shaped curve, the distal curve for the tip of the semilunar bone, and the proximal curve for the os magnum. (G. G. Davis, Surg., Gyn., and Obstet., August, 1923.)

osteo-arthritis sometimes set up by the trauma to the easily injured irregular surfaces of the os magnum and semilunar may result in an impairment of joint motion that makes this method not always applicable.

As Speed points out, if reduction is accomplished, the reduced bone will act as a foreign body causing disability for many years.

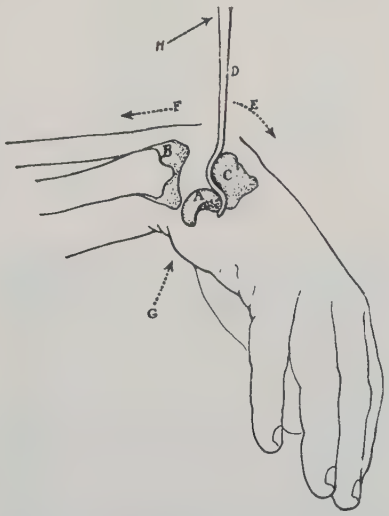
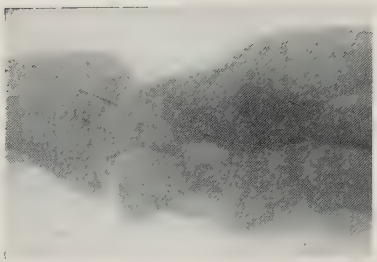


Fig. 1991.—Diagram showing D the "skid" and its relationship to A, the dislocated semilunar bone; B, the radius; and C, the os magnum. The arrows mark the direction of the various forces applied to accomplish the reduction of the semilunar. F is the counterextension applied to B. G is the pressure applied to the volar surface of the wrist against the semilunar bone. (G. G. Davis, Surg., Gyn., and Obstet., August, 1923.)

Early non-operative or closed reduction gives a good result.

Conwell has reduced 3 cases by the "broom-stick" method with practically perfect results (see Figs. 1992–1994).

Speed followed 9 early reduced cases of semilunar anterior displacement, and found that after six years all had good if not perfect results.



1992.

1993.

Figs. 1992, 1993.—Anterior dislocation of the semilunar. Lateral and anteroposterior views (Conwell).

Fig. 1994.—Right semilunar dislocation after reduction. Note amount of extension of wrist. Note amount of flexion of wrist (Conwell).

Fig. 1995.—Dislocation of the cuneiform. Separation of hand (Jacobs-George).

Speed has had 4 cases of early reduction of dorsal semilunar displacement. One of these was, remarkably enough, a bilateral case. The results after two years are very good.

3. *Removal of the Semilunar.*—In complete displacements (see Fig. 1987) and in incomplete displacements that come to operation, including old dislocations, removal of the bone is the wisest treatment.

It is a mistake to force a pathologically changed bone into a contracted and shrunken bed; even if it ever could be done it would result in no benefit.

Operation for Removal of the Displaced Semilunar Bone.—Adams uses the anteropalmar incision 2 inches long to the ulnar side and parallel to the tendon of the palmaris longus muscle. Avoid opening tendon sheath. Annular ligament may require division. Develop the median nerve. Retract to radial side. Retract flexor sublimis tendons to the ulnar side. Expose the displaced bone through the tendons of the flexor profundus. The anterior ligament of the wrist will be found attached to the anterior horn of the semilunar. Close wound without drainage. Cock-up splint. Motion after forty-eight hours. Splint omitted in one week.

Results.—In *closed early reduction* perfect results may be expected.

Open reduction shows permanent disability in flexion and extension movements of the wrist.

Removal of the Semilunar.—Five of the 8 cases recorded by Adams have about three-quarter flexion and extension, and are doing their former work. The only complaint is a weakness of the wrist and hand in hyperextension.

Three are at work, but doing lighter work than before the accident, complaining of some pain and some limitation of flexion and extension. These 3 cases have 15 degrees of flexion and extension. Removal of the semilunar bone causes an interference with perfect wrist function.

Speed records having removed 20 dislocated semilunar bones—6 semilunar with scaphoid, and 11 scaphoid bones after fracture, with satisfactory functional results.

Forward dislocation of the semilunar may result in median nerve pressure which may be so severe as to give rise to symptoms of median nerve paresis and paralysis. The atrophy of the intrinsic muscles of the hand resulting will be difficult to overcome.

Upon early removal of pressure, full return of function will take place; consequently, if median nerve involvement appears at once after a dislocation, immediate operative reduction is indicated. Non-operative reduction would only increase the damage to the nerve possibly irreparably. Speed records having seen 7 median nerve involvements.

Adams contends that the persistence of the dorsal displacement (Type C) produces a permanent disability of the wrist. Even after removal of the semilunar in old cases, unless this persisting dorsal displacement is corrected, the operation of removal will not be attended by satisfactory wrist-joint movement.

Cohn records a case of removal of the semilunar twelve weeks after dis-

placement with a slight limitation of motion in flexion of the wrist as the result. Cohn uses the Thompson approach to the lower end of the radius.

The *prognosis* in carpal dislocations will depend, as Speed points out, upon: (1) the degree of the dislocation; (2) the length of time that has elapsed since the dislocation; (3) the presence or absence of an accompanying fracture of the same or neighboring bone; (4) the success or failure of an early attempt at reduction.

COMPLETE BACKWARD DISLOCATION OF THE FIRST PROXIMAL PHALANX OF THE THUMB

The deformity of this dislocation is well shown in Fig. 1996. The articular portion of the base of the phalanx has entirely left the articular portion of the head of the metacarpal bone. The two lateral ligaments are torn. The anterior or glenoid ligament is likewise torn at its attachment to the

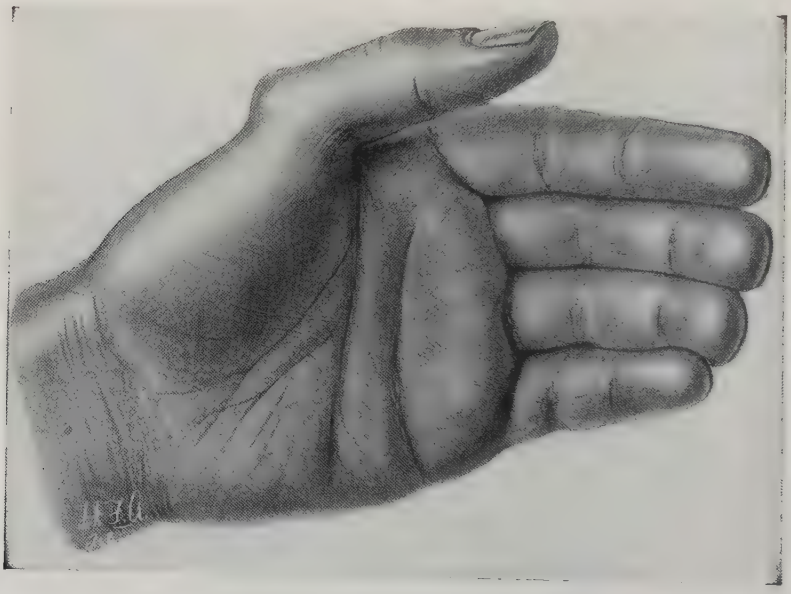


Fig. 1996.—Backward dislocation of first phalanx of thumb. Note deformity.

metacarpal bone and is displaced with the phalanx. Ordinary traction only serves to increase the difficulty of reduction, as is illustrated in Fig. 1998. The proper method of manipulative reduction is by completely extending the thumb so as to relax the tight adductor brevis and flexor longus pollicis tendons and then to push the base of the phalanx (Fig. 2000) forward, advancing at the same time the torn glenoid ligament over the end of the metacarpal head; flexion will then complete the reduction. Immobilization in a straight position for five days, and after this painless passive and active movements, together with massage, are indicated. Should reduction be impossible by manipulation, operative treatment will become necessary.

Fig. 1997.—Same as Fig. 1996. Note head of metacarpal and how it is held by adductor brevis and flexor longus pollicis.

Fig. 1998.—Note that traction alone accomplishes no reduction, but a very tight grasp of the metacarpal head by flexor longus pollicis and the flexor brevis.

Fig. 1999.—Proper method of reduction. Dorsal flexion of thumb (true extension); traction through dorsal pressure by thumbs so that base of phalanx is advanced over head of metacarpal.

Fig. 2000.—Dorsal dislocation of the terminal phalanx of the thumb. Reduced by forced extension and sliding of the extended phalanx over the end of the first phalanx. Note complete separation of bones. Glenoid ligament is torn and attached to the displaced phalanx.

Fig. 2001.—Dorsal dislocation of the first phalanx of the thumb. *x*-Ray. Rather easily reduced by slight extension and traction. Note that the articular surfaces touch each other at the margins of the bones.

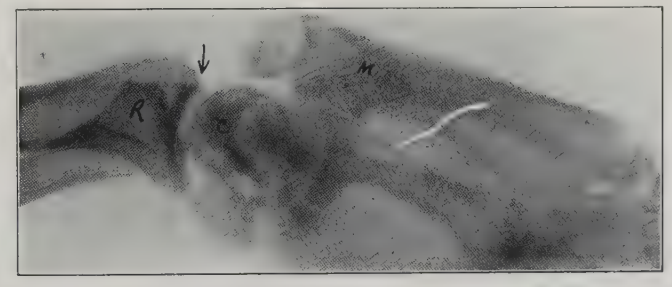


Fig. 2002.—Dislocation of the bases of the metacarpal bones: *C*, Carpus; *M*, metacarpal; *R*, radius. Arrow points to wrist-joint. (Massachusetts General Hospital Clinic.)

DISLOCATION OF THE HIP

A line drawn from the anterosuperior spinous process of the ilium to the tuberosity of the ischium passes about midway across the acetabulum. The portion of the bony pelvis posterior to this line is called the outer plane of the pelvis. The portion of the pelvis anterior to this line is called the inner plane of the pelvis (Allis). The hip is dislocated by a force bringing leverage to bear upon the head of the bone when the thigh is flexed upon the abdomen. The head of the femur leaves the acetabulum through a rent in the under portion of the capsule of the joint.

The first movement of the head in being dislocated is downward. According as the head of the bone slips to the outer or the inner plane of the pelvis will the dislocation be classified as an outer or an inner dislocation; that is, a posterior or an anterior dislocation. Of course, in either position, whether the outer or the inner, the head of the bone may be high up or low down. The anterior portion of the capsule of the hip-joint is far thicker

than any other portion of the capsule. This thickened portion Bigelow called the Y-ligament.

Symptoms.—The symptoms of an outward or dorsal dislocation of the hip: The limb is inverted, somewhat shortened, flexed slightly upon the abdomen, the toes of the dislocated limb rest upon the instep of the other foot, the head of the bone can be felt above the acetabulum. The adduction, flexion, and the rolling inward of the limbs are signs of a dislocation of the hip outward.

Fig. 2003.—Dislocation of the right hip-joint. The head of the femur resting upon the dorsum of the ilium. Note the adduction and flexion of the thigh in characteristic attitude.

The symptoms of an inward or anterior dislocation: The thigh is flexed upon the abdomen, abducted, rotated outward; the heel is raised, the foot everted.

Reduction.—The method of reduction of an outward or dorsal dislocation: Stimson advises very properly the passive method in uncomplicated cases. The patient is placed prone on a table, the dislocated leg is allowed to hang over the end of the table while the sound leg is held in line with the body by an assistant. The surgeon grasps the ankle of the dislocated leg and flexes the knee to a right angle. The weight of the leg pulling on the muscles about the hip gently but evenly often, aided by pressure on the calf

of the flexed leg on the part of the surgeon, will reduce the dislocation. A slight rocking of the leg may facilitate reduction.

Allis' Method.—The patient lying supine, the pelvis being held fixed by two assistants, the surgeon kneels by the patient's side, and if the right femur is dislocated he grasps the ankle with his right hand and places the bent elbow of his left arm beneath the popliteal space: (1) He now turns the bent leg outward and lifts upward (skyward); (2) then turns the bent leg inward and brings the femur down in extension.

Fig. 2004.—Dorsal dislocation of the left hip. Note the characteristic attitude. The knee is more adducted than in case of Fig. 2003.

Fig. 2005.—Anterior dislocation of the right hip. Note characteristic eversion and attitude of the right lower extremity. (Case of Burrell, Boston City Hospital Clinic.)

The method of reduction of an inward or anterior dislocation:

Allis' Direct Method.—(1) Flex and abduct the femur. (2) Make traction outward. (3) Fix the head by digital pressure and adduct.

Allis' Indirect Method.—Extension, adduction, and outward rotation are the movements made. The patient is lying on the floor on a blanket with the femur flexed. The surgeon places his bent elbow beneath the flexed knee and grasps the ankle with the other hand; he then extends with

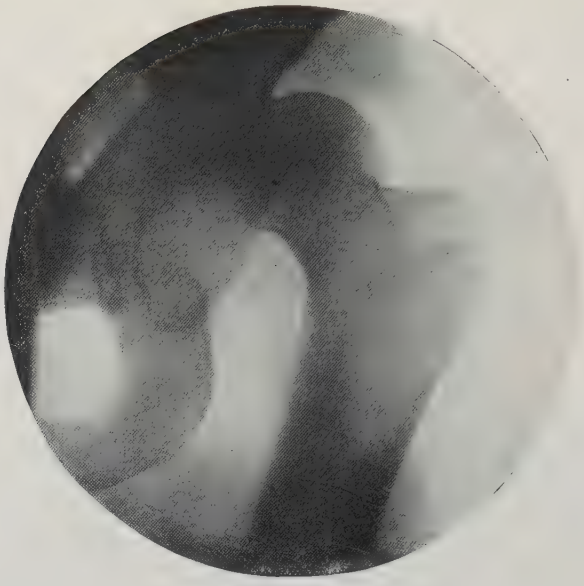


Fig. 2006.—A dorsal and upward dislocation of the hip (George).

Fig. 2007.—Posterior or dorsal dislocation of the left hip. Note the characteristic attitude of the left lower extremity. Flexion, adduction, inversion of the thigh. (Case of Burrell, Boston City Hospital Clinic.)

traction in the line of the long axis of the femur, adducts, and rotates outward.

Bigelow's Method of Reduction of a Dorsal or Posterior Dislocation.—The patient lies in same position as described above in Allis' method. The thigh is flexed, adducted, slightly inverted, lifted, circumducted outward, and extended.

Bigelow's Method of Reduction of Thyroid or Anterior Dislocation.—The thigh is flexed on abdomen to a right angle, abducted, and rotated inward with adduction, and is finally extended.

DISLOCATION OF THE PATELLA

Fig. 2008.—Lateral dislocation of right patella (Massachusetts General Hospital).

Fig. 2009.—Incomplete dislocation of the right patella outward. Its inner border rested in the intercondyloid notch. Reduced by ether and lifting and pushing into place. Same case as that seen in Fig. 2008. Reduction is usually easy (Massachusetts General Hospital).

Fig. 2010.—Dislocation of the foot posteriorly without a fracture of the tibia (Conwell, Alabama).

Fig. 2011.—Dislocation of the foot backward. Before operation (Conwell).

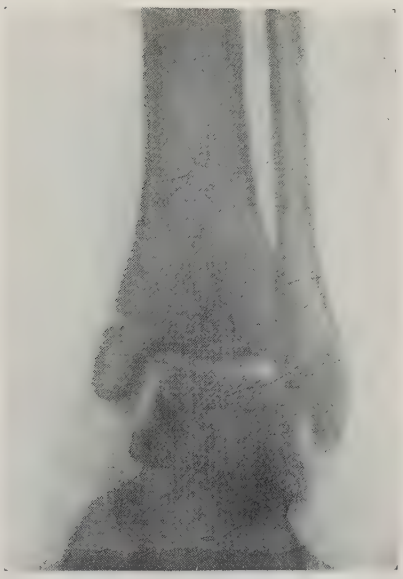


Fig. 2012.—Dislocation of foot backward, anteroposterior view (Conwell).

Fig. 2013.—*x*-Ray of ankle after reduction of the dislocation of foot backward (see Fig. 2010—Conwell).

Fig. 2014.

Fig. 2015.

Fig. 2016.

Fig. 2014.—Deformity of dislocation of the foot backward. Compare Fig. 2010.
Fig. 2015.—Dorsal flexion possible after reduction of posterior dislocation of the foot (Conwell).
Fig. 2016.—Extension possible after reduction of dislocation of the foot backward (Conwell).

CHAPTER XLIII

THE SURGEON AND THE LAW[1]

A. General statement—B. The Roentgen ray in court—C. Certain acts or omissions—D. Abstracts of court decisions in fracture cases—E. Conclusions.

A. GENERAL STATEMENT

THE standard by which the law tests the skill and care of the surgeon in the diagnosis and treatment of fractures is the same standard applied to him in the diagnosis and treatment of all other phases of the healing art. This legal standard is an arbitrary and artificial one, but is held to be just, and is expressed by the court in the following language:

A physician and surgeon is required to possess and to exercise that degree of knowledge, skill, and care with good judgment and diligence ordinarily possessed and exercised at the particular time by the average of the members of his profession in good standing in similar localities in the light of the then present state of medical and surgical science.

Gilette v. Tucker 67. Ohio State Report 106 Supreme Court of Ohio.

Cyclopedia of Law and Procedure, vol. xxx, pp. 1570.

The surgeon caring for a fracture is incurring a far greater risk of exposure to the annoyance and expense of a damage suit than in dealing with other surgical cases. Probably a majority of malpractice suits are instituted for negligence in the treatment of fractures.

Legal Principles on Which the Surgeon Stands.—It will be seen that the surgeon under the law is expected to qualify in three particulars:

1. To possess learning, skill and experience.
2. To exercise care and diligence.
3. To use his best judgment.

1. The degree of learning, skill, and experience required of the surgeon is that which is ordinarily possessed by the members of his profession in good standing as a whole. It is ordinary skill, not unusual skill. A reasonable, fair, and competent degree of skill is demanded. (Leighton v. Sargent, 59 A. D. 388.)

2. The degree of care and diligence required of the surgeon is reasonable and ordinary care and diligence applied to accomplish the purpose for which he is employed. He is not expected to apply extraordinary care.

3. When undertaking to treat a fracture the surgeon stipulates to exercise his skill and apply his diligence and care with his best judgment. In every case of fracture there must be great discretion in the selection of the treatment. Freedom from errors of judgment is never expected.

[1] Material for this chapter is taken largely from a paper by Clyde L. Young, Esq., by permission, Journal-Lancet, vol. 38, 1918, p. 132, and from papers by C. M. Dutcher, Esq., Jour. Iowa State Med. Soc., 1920, p. 331, and by L. E. Eastman, Esq., Ohio State Med. Soc. Jour., 1921.

The above general principles governing under the law the liability of a surgeon are well defined. The application of these principles is often extremely difficult.

When does a surgeon possess less than ordinary learning and skill? Under what circumstances has a surgeon failed to use the usual care to which a patient is entitled? In what cases is there faulty judgment?

A consideration of these questions will serve to cover the essential legal bases of the surgeon in his relation to his fracture patient. These considerations are very accurately defined in the law.

The Degree of Learning and Skill Required.—The skill or ability required is that which physicians of ordinary ability and skill practising in similar localities, with opportunities for no larger experience, commonly possess. This is not the skill exercised in the profession in the locality where he practices. (Gram v. Boenre, 56 Ind. 497.) (Vitta v. Fleming, L. R. A. 1916—D., p. 644.) (Whitesell v. Hill, 37 L. R. A. 838.) (Minnesota.) The standard of learning required of physicians and surgeons outside of the great cities in rural communities is being materially raised, so far as their liability to malpractice suits is concerned. This is a move in the right direction.

In determining the degree of learning the law regards the state of medical science at the time. The law has no toleration for quackery. In passing judgment upon the degree of skill of a given surgeon the law takes cognizance of the state of thought and practice of the surgical profession at that particular time. When a surgeon poses as a specialist having skill and learning additional to that of the general practitioner he necessarily exposes himself to extra liability. This is natural and reasonable.

The surgeon must exercise his best judgment. If he has used his best judgment, he is not legally responsible if his treatment is unsuccessful. It is, therefore, very important to know what the law means by best judgment.

The rule concerning surgeons is an exception to the law of negligence. If a surgeon collects all data in a given case and uses his best judgment in treatment, he is not liable even if the result is unsatisfactory. Malpractice cases may have to do with errors of judgment and with negligence in collecting essential data. When a man acts according to his best judgment in an emergency, as in a fracture case, but fails to act judiciously, he is not chargeable with negligence. The act may be called a mistake, but it is not carelessness. Allowance is made, too, for the constitution of the human body and mind with which the surgeon deals. (See Oregon case, Williams v. Poppleton, 3 Ore. 147.)

Moreover, the law takes account, in judging the liability of a surgeon, of the fact that surgeons deal with a profession, an applied science. (See Minnesota case Staloch v. Holm, 9 P. R. A. (N. S.) 712.) If the training and experience of qualified surgeons in consultation over a surgical problem of treating a definite fracture case leads them to vary in the opinions expressed, certainly no twelve men in a box and no one man on the bench or any member in an appellate court can better decide. The application of science to art is bound always to be most difficult at times.

The basis of the proof of a surgeon's negligence is often uncertain and unsatisfactory and naturally biased by family and friendly considerations. The latitude allowed the judgment of the surgeon is limited to cases of doubt as to conditions present or the treatment used. In the absence of doubt in these particulars variation from the ordinary custom would be chargeable with negligence.

Experiments are not permissible under the law. If it can be shown that the patient cannot have the ordinary treatment, then the surgeon may be justified in using an unusual one. It has been held that although the ordinary practice in case of a fracture of both bones of the leg would be to extend the leg, yet if the character of the damage to the leg precluded this, extension and counterextension, a failure to use such extension and counterextension does not show want of skill or negligence. (See Barnes v. Means, 82 Ill. 379, 25 A. R. 328.)

In passing on the skill or judgment of a surgeon regard must be had to the recognized practice or customs of his particular school of practice and not to those of other schools. (Batten v. Wiggin, 81 A. D. 593. Force v. Gregory, 22 L. R. A. 345.)

Want of success is not in itself evidence of negligence. A surgeon does not warrant or insure or guarantee that his treatment will be successful or even beneficial. Even if there be an improper diagnosis or improper treatment, or both, if the patient suffered no injury therefrom the patient is without remedy, if he fully recovers.

B. THE ROENTGEN RAY IN COURT[1]

No case has yet appeared in the reports of court cases in which there was use of the *x*-ray upon anything other than the human body. Within a year after the announcement of Roentgen's discovery of the *x*-ray the first case appeared in an American court admitting the *x*-ray as evidence. (Smith v. Grant Dec. 3, 1896, 29 Chi. Leg. News 145.) A picture of the neck and head of the femur was admitted. In 1919 the New York Court (Leone v. Booth S. S. Co., 232 N. Y. 183, 1921) took judicial notice of the fact that *x*-rays were a common adjunct to hospitals the world over and inferred that a supposed sprain would have been disclosed as a fracture if an *x*-ray had been taken.

For the lawyers, the *x*-ray is practically limited to the field of evidence; while the physician and surgeon are concerned with it as a curative agent, sometimes a dangerous agency, and as a diagnostic measure.

The same tests of admissibility in evidence shall apply to a radiographic plate or picture that are applied in the case of other pictures.

The liability which is at present observed as arising from the *x*-ray is of three types:

1. Liability arising out of the application of the *x*-ray as a therapeutic agent.

[1] The material for this section has been taken by permission from Professor Wilson's valuable contribution. Lyman P. Wilson, Cornell Law Quarterly.

2. Liability for injuries arising out of its application as mechanical aid in diagnosis.

3. Liability for failure to use the *x*-ray as an aid to diagnosis or treatment.

We are concerned especially here with the third type of liability—liability from failure to use the *x*-ray as an aid to diagnosis and treatment. For a time the courts were so busy with the matter of the proper application of the *x*-ray as evidence, and so absorbed with the dangers then present in the new appliance, that there appeared no suggestion that there might be a duty to use the *x*-ray for any purpose. The first case to raise this question appeared in 1910. (Wills v. Ferry Lbr. Co., 57 Wash. 658, 107 Pac. 869, 29 L. R. A. (N. S.) 426, 1910.) Courts began to take judicial notice that many fractures could be definitely proved only by this means of *x*-ray examination. (Ansomus v. People, 47 Colo. 167, 107 Pac. 204, 19 Ann. Cas. 491, 1910.)

Whether it is negligent not to have used the *x*-ray in diagnosis is a question which must be left to the jury to determine with the aid of expert testimony. (Viita v. Nolan, 132 Minn. 128, 155 N. W. 1077, 11 N. C. C. A. 753 and note (1916) and McGraw v. Kerr; supra, note 130.) The availability of *x*-ray outfits is now so common that its unavailability is not adequate ground for not having used it. It is clear that we have not reached the point where it can be said to be negligence as a matter of law not to have employed the *x*-ray in any case. No sharp distinction can be made between the fields in which the *x*-ray is a necessity and those in which it may be dispensed with. In this uncertainty the failure to use the *x*-ray cannot be said to be more than an error of judgment in treatment and will, therefore, not be actionable. The jury must decide whether it was negligence in the particular case not to have taken more than one picture in aid of diagnosis or whether (Wojciechowski v. Coryell, 217 S. W. (Mo. App.) 638, 1920.) it was negligence not to have taken subsequent *x*-ray pictures to determine how the processes of repair were progressing. (Snearly v. McCarthy, spra. note 124.)

The question of diligence in the use of the *x*-ray appears in a case in which there was a motion for a new trial based on the introduction of newly discovered evidence, disclosed by an *x*-ray picture taken subsequent to the hearing. (Van Taider v. Birmingham R. L. & P. Co. 202 Ala. 474, 80 So. 858, 1919.) The court said in this case: "It is a matter of common knowledge that in cities the use of the *x*-ray for the discovery and diagnosis of internal injuries and abnormal conditions of the human body is of common occurrence."

Professor Lyman P. Wilson closes his paper on the *x*-ray, from which the above facts have been taken, with these words:

Science is still rather too far in advance of the law. Where science leads, the law must follow with an open mind, endeavoring always to apply new discoveries with full consideration of their basic nature, rather than in subservience to existing technical rules.

We may yet with profit return to the first *x*-ray case (Smith v. Grant) and find in it the proposed receptive attitude which the courts must assume and maintain if future discoveries in science are to meet with that corresponding reaction in the law, which is necessary if a rational development is to be attained.

The jurist cannot introduce radically new elements into his scheme without first giving careful consideration to sweeping adverse results which may be produced in the entire community, by disturbing that thing which Dean has aptly designated as the social interest in security.

I believe the time will come when the court will agree with the surgeon that an *x*-ray examination is compulsory and necessary in every injury to bone. The use of the *x*-ray will soon be required to avert the imputation of negligence.

C. ACTS OR OMISSIONS CONSTITUTING MALPRACTICE

1. A physician is not bound to render professional services to everyone who applies and is therefore not liable for arbitrarily refusing to respond to a call, although he is the only physician available.

2. Failure to discover the nature of an injury is actionable, if there is reasonable opportunity for examination and its nature can be discovered by the exercise of ordinary care and diligence. It has been held that if a physician, who, by reasonable care, ought to discover that an injury will not yield to the usual treatment and that he cannot benefit the patient, fails to make such discovery and advise the patient thereof, he is guilty of negligence.

3. A wrong diagnosis, if followed by improper treatment, gives a right of action, assuming of course that the patient suffers injury therefrom. There is no liability on the part of the general practitioner for making a wrong diagnosis of a very rare case which can only be detected by a skilled expert.

4. As has already been indicated, failure to follow the established practice, to the injury of a patient, is ground for liability, except where the character of the injury is such that the patient cannot endure the most approved method of treatment in such case.

5. Abandonment or neglect of a case, where voluntary and unwarranted, resulting in increased pain and suffering on the part of the patient, renders the practitioner liable in damages. He is not chargeable with neglect because of intervals elapsing between his visits where the injury requires no attention during the intervals, but is negligent where attention is required. If he temporarily leaves his practice, neglect cannot be imputed to him if he makes provision for the attendance of a competent physician and notifies his patient as to his leaving and indicates who will attend in his stead. Leaving one in a critical condition, however, without reason or sufficient notice so as to enable the procurement of another attendant is a dereliction of duty.

6. Although a surgeon may have exercised a proper degree of skill and care in his treatment of a broken limb, it is his duty to give his patient all necessary and proper instructions as to what care and attention the patient should give the limb in the absence of the physician and the caution to be observed in the use of the limb before it is entirely healed. Failure to discharge his duty in this respect may make him liable in damages.

7. As already indicated, a physician possessing the requisite qualifications and applying his skill and judgment with due care is not ordinarily liable for damages consequent upon an honest mistake, or an error of judgment in making a diagnosis, or in his method of treatment, where there is reasonable doubt as to the nature of the physical conditions involved, or as to what should have been done in accordance with recognized authority. There is a fundamental difference, however, in malpractice cases between mere errors of

judgment and negligence in previously collecting data essential to a proper conclusion. If he omits to inform himself as to the facts and circumstances and injury results therefrom, he is liable however careful he may have been in reaching a conclusion upon the assumed facts.

8. He is exonerated from liability where the patient is guilty of contributory negligence. This is one of the common defenses in malpractice suits. It is obviously the duty of a patient to co-operate with his physician and to conform to the necessary prescriptions and treatment and to follow all reasonable instructions given. A fair statement of the law is as follows:

(*a*) If it appears that there was no breech of duty on the part of the surgeon and that the injury was due entirely to the patient's own negligence and failure to follow instructions, or such negligence or failure on the part of those whose negligence is chargeable to him, there can be no recovery at all.

(*b*) It may appear that while there was a breach of duty on the part of the surgeon, yet that no substantial injury would have resulted therefrom but for the patient's own negligence, or that of a third person whose negligence is chargeable to him. In such case the patient's negligence is one of the causes which approximately contributes to the injury and does not merely affect its extent. In such cases the negligence of the patient, though slight, as compared with that of the surgeon, will preclude a recovery altogether and not merely mitigate the damages.

(*c*) It may appear that there was a breach of duty on the part of the surgeon which even in the absence of negligence on the part of the patient would have caused some injury, or that the injury was aggravated by the negligence of the patient. This is equivalent to a case where an accident results in an injury caused entirely by the defendant, and where it was subsequently aggravated by the plaintiff. In such case, if it is possible to separate the consequences of the negligence of one from that of the other the patient's negligence does not bar recovery altogether, but merely mitigates the damages so the surgeon is liable for the injury resulting from his own breach while relieved from that resulting from the patient's own fault.

9. A surgeon is responsible for an injury done to a patient by want of the proper skill and care of his assistants. He is not ordinarily liable for the negligence of hospital nurses or attendants over whom he does not have direct supervision. However, in the state of North Dakota (in the case of Fawcett v. Ryder, 23 N. D. 20) the court has held that a surgeon, who is the owner of a private hospital run by him for profit in connection with the practice of medicine and surgery, is liable for the negligent acts of a nurse employed therein. Of course, partners in the practice of medicine are all liable for an injury to a patient resulting from the negligence of any one of the partners within the scope of the partnership business.

ILLUSTRATIVE CASES

In an Iowa case the plaintiff fell so that the clavicle was dislocated from the shoulder blade. The physician called declared it a case of fracture of the clavicle rather than dislocation. It appeared, however, that the dislocation was perfectly reduced and that the dressing and treatment used were such as reasonable care and skill exacted for the cure of a dislocated clavicle. Although at the time of the trial the bone was an inch inward and backward from its bed, it was held that under these circumstances the defendant was not liable regardless of his error in the diagnosis as he had nothing to do with the case after the first dressing was applied. In other words, the treatment being right for the actual injury the diagnosis became immaterial. (Tomer v. Aiken, 101 N. W. 769.)

So it has been held that a physician is not negligent because he is unable to discover a dislocation. If it appears that he gave the patient careful atten-

tion and made more than one thorough examination, and called in another physician for consultation, he is absolved from liability. (James v. Crockert, 34 N. B. 540.)

But a physician is answerable in damages for failing to discover a dislocation of the shoulder and fracture of an arm when he had reasonable opportunity to make an examination and the dislocation and fracture should have been ascertained by the exercise of ordinary care. (Manser v. Collins, 69 Kans. 290, 76 Pac. 851.)

Again, a physician is guilty of negligence where he omits to reduce a swelling and by reason thereof fails to discover that the real nature of an injury is a broken patella instead of a rupture of the ligaments.

In a Kentucky case (Burke v. Foster, 59 L. R. A. 277) the plaintiff was thrown to the ground in a runaway, so that his humerus was broken in one or more places and the head of the humerus was wrenched from the glenoid cavity. The defendant was called but failed to discover the dislocation and of course did not treat it. In consequence the muscles of the arm became atrophied and the shoulder-joint stiffened so that the arm was practically useless. The discovery was not made for some months so that it could not be remedied. The claim was made that the result was as good as is usually obtained in like cases. But the court said that many cases of injury or illness are recovered from without medical attention while many others of the same kind do not recover, although apparently the best medical attention is given. "Then it is equally well known that two or more cases of apparent similarity, treated by the same treatment, and indeed by the same physician, may, and often do, have directly opposite results as to recovery." It then says: "We think that when a physician undertakes to give his attention, care, and skill to a given case of injury or disease, the patient is entitled to the chance for the better results that are supposed to come from such treatment and are accorded by the science of his profession to a proper treatment. That the patient might have died in spite of the treatment, or that 'ordinarily' they did die in such cases, is no excuse to the physician who neglects to give his patient the benefit of the chance involved in a proper treatment of his case. . . . In this case the patient was entitled to an ordinarily careful and thorough examination of his injuries, such as the circumstances attending their infliction, the condition of the patient, and the surgeon's opportunities for proper examination, suggested and allowed. If the dislocation was discoverable by such examination and if the physician felt that because of lack of appliances, or lack of experience, he was unable to treat any peculiar feature of the injury, it was at least the right of the injured man to be apprised of his condition, that he might call in more skilled attention if he desired."

Fractures of the neck of the femur have given rise to a considerable line of cases. The difficulty of diagnosing a case of this kind has been recognized by the courts and in more than one instance has served the surgeon well in his defense. In an Oklahoma case (Champion v. Keith, 17 Okla. 204, 87 Pac. 846), the surgeon was absolved from liability for the failure to diagnose

a fracture of the neck of the femur, it being shown that he was a reputable surgeon, that he possessed the ordinary skill and ability required, that he took the precaution of calling in an assistant of perhaps even greater skill, that their examination was very thorough, and that all precautions and appliances at their command were used, it appearing from the evidence that a fracture of the neck of the femur is sometimes impossible to detect and distinguish from a dislocation.

The plaintiff, in a similar case in Colorado (Bennet v. Foote, 28 L. R. A. (N. S.) 136), recovered damages for her injury. The plaintiff injured her right hip and called the defendant to treat the injury. Upon his examination he announced that she had only sprained and severely bruised it when, as a matter of fact, she had sustained a fracture of the neck of the femur with a displacement of the outer fragment, which eventually caused a shortening of the limb from 2 to 3 inches. In sustaining the verdict of the lower court the supreme court said that a surgeon is only required to restore an injured limb to that degree of perfection which would result from the exercise of that degree of skill in treating the injury which is ordinarily possessed by members of the profession. A surgeon is not responsible for want of success unless it is the result of a failure to exercise ordinary care. Neither is he responsible for a mistake of judgment if he possesses the ordinary skill and used reasonable care in exercising it. The fact that an injured limb is defective after the patient has recovered is proper to consider in an action for malpractice, although it is not *prima facie* evidence of negligence of the surgeon treating it. That is, the mere fact that an injured limb has imperfectly healed does not of itself establish that the surgeon treating it was guilty of negligence, but in this case, the defendant, because of improper diagnosis, treated for a bruise rather than a fracture, and from the evidence in the case it was held that the defendant should have found that it was a fracture.

Another phase of liability is brought out in a Michigan case (Spaulding v. Bliss, 47 N. W. 210), where there was a fracture of about the lower third of the right femur. While the defendant was charged with a number of negligent acts it is sufficient that he was held accountable for the use of unnecessary force by an assistant selected by him in reducing the fracture, whereby a ligament of the knee was ruptured so that permanent injury resulted.

An Iowa case (Cozine v. Moore, 141 N. W. 424) involves the question of judgment. The plaintiff suffered two compound fractures of his left lower jaw. The flesh wounds were in the mouth and the segment of the jaw between the two fractures had been drawn out of position by the contraction of the muscles. Defendant, who was called to treat the case, constructed an interdental splint. There was an infection which caused some complications, but eventually a union resulted and, while the place of fracture was not readily discoverable by experts, the alignment was more or less imperfect. It was the claim of the plaintiff that there was another surgical method known to the profession which should have been adopted by the defendant, this consisting of drilling holes in the jaw in ends of the broken segments and

of drawing and holding the parts together with the use of a silver wire. It followed, however, that even the experts testifying for the plaintiff would hardly have adopted a different course. The court says: "All experts agree that very difficult cases present a zone wherein the best method becomes largely a question of judgment of the attending surgeon under the apparent circumstances of each particular case." That the appliance was painful or inconvenient and that infection resulted, and that the plaintiff's life was in great peril, were all matters incident to the natural results of the original injury. The best of surgical treatments might not be able to avoid them. Of themselves they are clearly insufficient to prove negligence of the defendant. For this reason the defendant was absolved from liability.

There is a Minnesota case (Viita v. Fleming, supra), which shows something of the part which the *x*-ray may be called upon to play in this class of cases. There the plaintiff sustained a fracture of the leg between the knee and ankle. The defendants, who were partners, reduced the fracture, put the leg into a plaster cast, which was allowed to remain for eleven days, when it was removed and a new one put on. Soon after this plaintiff observed that his foot turned outward. Although the attention of one of the defendants was called to this condition it continued to exist during his eleven weeks' stay at the hospital and still existed at the time of trial. The cause of this eversion was imperfect approximation of the fractured ends of the bones. The evidence tended to show that the failure to get a straight union was due to the omission of defendants to apply an extension weight to the injured limb. Negligence was further claimed because of their failure to use a fracture box, or to take an *x*-ray photograph for the purpose of diagnosis. At any rate, there was a poor result. The plaintiff's witnesses, reputable surgeons, stated that in their judgment the treatment was improper and not good surgery; that a fracture box should have been employed to hold the limb in proper position and an extension weight employed to draw down and overcome the muscular contraction. They also criticized the failure to take an *x*-ray photograph to determine whether the approximation of the bones was correct. The court held that this evidence was sufficient to warrant a recovery on behalf of the plaintiff. Although it does not appear to what extent the claim as to the use of the *x*-ray influenced the jury, it was an element in the case.

Only a few months ago a decision was rendered in a notable Iowa case where the defendant, failing to use the *x*-ray, was charged with negligence for that reason. (Snearly v. McCarthy, 161 N. W. 108.) There was a simple fracture of the femur which was promptly reduced. There was great difficulty in caring for the injury and securing a union. There were several operations, two of them by Dr. Murphy of Chicago, and after about a year and a half of effort a union was secured, the leg being about $1\frac{1}{2}$ inches shorter than the other. All sorts of negligence were claimed, one of the principal grounds of recovery relied upon being a failure to use the *x*-ray in making the diagnosis and later in the course of the treatments, especially during the early stages. It was shown that it is entirely optional with physicians

whether they would use the *x*-ray in such cases in the first instance. And the conclusion was reached that as the purpose of such use is to make the diagnosis no negligence is to be inferred from the failure to use it where a proper diagnosis can be made without it. The nature of the fracture having been discovered at the outset, an *x*-ray examination would have added nothing to it, so no liability attached.

In a still more recent case, however, the same court has held that it was proper for the plaintiff to show that *x*-ray machines were available to the defendant so he could have used one in diagnosing the case, which was a fracture of the humerus in which there was such a separation of the broken ends that the musculospiral nerve was drawn in between the pieces. The arm is useless as a result. The evidence shows that a surgeon to be certain that the nerve is not caught should take an *x*-ray, and that failure to use it is a circumstance to be considered in determining whether proper care was exercised. (Ingersen v. Carr 164 N. W. 217.)

While it thus appears that it is not yet deemed negligence in itself for a surgeon to fail to use an *x*-ray in making his diagnosis and in following the course of treatment, there is no doubt that as the device becomes more common and as surgeons make more frequent use of it in determining the nature of fractures and the treatment which should be used there will develop the principle that failure to use it is evidence of negligence in those cases where it appears that by its use a more accurate diagnosis could have been made.

D. ABSTRACTS OF COURT DECISIONS IN CERTAIN FRACTURE CASES

These abstracts are assembled from the abstracts of medicolegal cases appearing from time to time in the Journal of the American Medical Association. They are carefully abstracted and compiled and may be depended upon for illustrative purposes.

MEDICOLEGAL

EVIDENCE AND DAMAGES IN ACTION FOR MALPRACTICE IN TREATING A FRACTURE OF THE CLAVICLE

(*Duffy vs. Charters (Mich.), 147 N. W. R. 541*)

The Supreme Court of Michigan affirms a judgment for $1080 damages in the plaintiff's favor, for alleged malpractice in the treatment of an oblique fracture of the left clavicle. The plaintiff's claim, supported by his own testimony and that of two others who were present, was that when the defendant came to his house all he did was to pick up his arm and place it diagonally across his breast so that the points of the fingers of the left hand were against the lower part of the right shoulder, above the armpit and below the top of the shoulder; that thereupon he applied bandages, which the defendant claimed was done in the approved method known as Sayre's dressing, but, it was claimed by the plaintiff, was not done as Sayre's method required. Whether the defendant was negligent in that he did not use a proper method in reducing the fracture was the question.

A medical witness produced on behalf of the plaintiff was asked a hypothetic question based on what the lay witnesses testified was done by the defendant when he put on the bandages. It was urged that the question was incomplete and so insufficient as to have no value in assisting the jury in determing the defendant's responsibility. The question did not contain what the defendant claimed he did in reducing the fracture, but stated substantially what the plaintiff claimed he did, as testified to by the witnesses present. An-

other physician described the proper method to be used in reducing such a fracture. The court holds that the testimony of the experts being based on the testimony of the plaintiff's witnesses, it was proper to have their answers stand. The question of the value of their evidence and that of the other witnesses for the plaintiff was for the jury, and was properly submitted by the trial court.

It was contended that there was a fatal variance between the plaintiff's declaration and attempted proof of a want of proper union of the broken ends of the clavicle. The declaration charged failure to put the bone or bones of the shoulder properly in apposition and to use the proper means for so placing and keeping them in apposition. The plaintiff argued that the false or fibrous union shown by the proofs was the natural result of imperfect apposition, as set forth in the declaration, and that it was therefore not necessary to specifically allege it. This was supported by the testimony of the physicians, who testified that the first step in the treatment of such a fracture is to get the ends of the bone together and keep them there, if possible, and, unless this is done, no perfect union results. The court thinks the declaration was sufficient to warrant receiving this evidence.

The jury were instructed that, for the pain and suffering which the plaintiff would have actually sustained by reason of this broken clavicle and its treatment, if properly treated, he could not recover damages, because the defendant was not responsible for that. But for the pain and suffering which were extra, if any, which was caused by the defendant, the plaintiff could recover. Under the issue in this case, it was entirely proper to submit to the jury the question of compensation for extra pain and suffering.

FAILURE TO INVERT THE FOOT IN THE TREATMENT OF POTT'S FRACTURE

(Marchaud vs. Belin (Wis.), 147 N. W. R. 1033)

The Supreme Court of Wisconsin affirms a judgment for the defendant, who was charged with malpractice in the treatment of Pott's fracture. The court says that the evidence showed that the fracture was a severe one, in which the fibula was splintered and the ligaments of the ankle-joint were ruptured; that the foot was much swelled and discolored, and the skin was partly abraded in places at the time of the first treatment. As to the condition at that time, January 23d, and from then until about February 13th, there was no evidence other than that of the defendant, and if his evidence as to the conditions existing and the treatment given was true he was guilty of no malpractice. The plaintiff, aged fifty-two, sustained the injury January 23d, by falling from a ladder.

It was contended in the plaintiff's behalf that, since the evidence showed that the conditions testified to by the defendant did not usually obtain in ordinary Pott's fractures for so long a time, the jury had a right to find that they did not in this case. Hence, since it was shown that in cases of ordinary Pott's fractures the danger of gangrene was usually passed in from seven to ten days, and since bony union does not take place until the third week, the jury might find malpractice from failure to invert the foot after the danger of gangrene had passed and before bony union took place. The difficulty with this contention was that the plaintiff's fracture was not an ordinary Pott's fracture, but a severe and complicated one; that there was nothing inherently or obviously incredible about the defendant's testimony as to the conditions found the first day he examined the leg, or as to their continuance for the length of time shown. The trial court, therefore, properly held that such conditions must be held as verities, since there was no evidence to the contrary.

Another claim made was that the evidence of the defendant showed that he was ignorant of the practice of inverting the foot in cases of Pott's fractures, and therefore did not do it in this case. Conceding, for the sake of argument, that this was true, still, if the treatment he gave was the proper one under the conditions existing, his ignorance became immaterial. He said, however, that the reason he did not invert the foot up to about February 13th was because he feared gangrene, and that thereafter bony union began, and he did not deem it good practice then to invert it. The treatment given under the conditions as testified to by the defendant was practically sanctioned by all the physicians who testified as to what constituted good practice. It was therefore shown that the

defendant exercised such care and skill and pursued such treatment as physicians and surgeons in good standing usually exercised and pursued in the same or similar localities under the same or similar circumstances. This measured the extent of his undertaking.

In an action for malpractice it is incumbent on the plaintiff to show wherein the defendant has been negligent or failed in his duty under the circumstances or conditions existing in the case that is tried. It is not enough to show that generally, or under other conditions, the conduct complained of might be found negligent.

TREATING ALLEGED COLLES' FRACTURE AS SPRAIN—RELATION OF DIAGNOSIS AND TREATMENT—CONSIDERATION OF RESULTS

(Willard vs. Norcross (Vt.), 85 Atl. R. 904)

The Supreme Court of Vermont reverses a judgment for malpractice obtained by the plaintiff; dismissing the plaintiff's petition with costs. The court says that this was the third time this case had come to it from a jury trial. The plaintiff had a verdict and a judgment each time. But it was fair to presume that she had now made as good a showing on it as she ever could, and, in view of this and of the history of the case, the court thinks it ought to be ended here. The plaintiff had slipped and fallen forward onto her outstretched hands and hurt her wrists. She called the defendant in the opening of her case, and he testified that he had practised his profession for more than twenty-five years; that he undertook the professional care of the plaintiff, and, after a careful and satisfactory examination, diagnosed a sprain of both wrists, but found no fracture; that in his treatment of her he used only one form of splint, namely, a pillow to support her hands and wrists, which were in no way bound to the pillow, but only rested on it. Other testimony on her part, given by two physicians, tended to show that she had at some time suffered an impacted Colles' fracture of both wrists.

On overruling a motion to remand the case, and dismissing a petition for a new trial, the court says that it must be admitted that there was evidence tending to show that the plaintiff's injuries were, in fact, fractures. The defendant treated them as sprains. Was he negligent in making his diagnosis? This was no more than asking if, in his effort to ascertain the character and extent of the injuries, he had exercised the care and skill exercised by physicians and surgeons in the examination of like cases in that locality. If this question was answered in the defendant's favor, liability could be established only by proof of negligent treatment; and, in proving this, it must be remembered that his mistake in the diagnosis was free from legal fault. In other words, treatment was to accord with the diagnosis; and, in judging it, it must be referred to the diagnosis, assuming, of course, that there was no negligence during the treatment in not discovering the true nature of the injury.

A physician is bound to give his patient a careful and thorough examination, so far as the circumstances will admit, using such care and skill and such methods of diagnosis for discovering the nature of the ailment or injury as are required by the rules of good local practice. If, in the exercise of such care and skill, either at the first examination or during the subsequent treatment, the plaintiff's fractures would have been discovered, the defendant's failure to discover them would amount to actionable negligence. The defendant's conduct in this behalf must be judged by what he saw and knew, or ought to have seen and known, at that time, not by what may have developed or come to light since; and, if conditions were such that the nature of the injuries became a matter of judgment merely, the defendant could not be held liable, though he erred. The conduct of a physician is to be judged, not by what usually appears and can be discovered in such cases, but by what appears or can be discovered in the instant case.

Everything went to show that this was not a usual case, but an unusual one, with conditions so obscure that the defendant's failure to discover the fractures, if, indeed, any existed, was not due to professional negligence. The court does not say that such negligence could not be established by circumstantial evidence, nor that cases might not come up in which the result itself might not afford some evidence thereof; but here the result strongly made in the defendant's favor. The plaintiff's recovery was so complete, both as

regards function and deformity, as to indicate very strongly that the defendant's mistaken diagnosis, if it was such, was not due to negligence. The evidence was overwhelmingly to the effect that the result was as good as could be expected by the most skilful treatment. And the radiographs before the court showed such a complete and perfect restoration of the injured wrists that any abnormal conditions still existing were so slight as to escape the untrained eye. This result, however, was not to be taken as conclusive on the question of the defendant's liability for negligent treatment. For, though the ultimate result was all that could be expected, if the defendant negligently adopted a course of treatment which resulted in greater suffering or longer disability than would otherwise have followed the injuries, he would be liable to that extent. The question of negligent treatment, as has been seen, was to be referred to the diagnosis. If this was free from negligence, and the treatment was in accord therewith, no cause of action for malpractice existed.

UNSUCCESSFUL TREATMENT OF FRACTURE WITHOUT ROENTGENOGRAM

(De Bruine vs. Voskuil et al. (Wis.), 169 N. W. R. 288)

The Supreme Court of Wisconsin not only reverses a judgment for $1800 damages obtained by the plaintiff for injuries alleged to have been sustained by reason of negligence on the part of the defendants in the treatment of a fracture of the tibia of the plaintiff's left leg about 2 inches below the knee, but remands the case with directions to dismiss the plaintiff's complaint on the merits. The court says that the plaintiff was a woman forty-nine years old. The accident occurred November 5th. The defendants reduced the fracture and placed it in a fracture box in the ordinary way with Buck's extension, attaching a weight of 26 pounds. December 20th, defendant Voskuil removed the apparatus, a part of the weight having been taken off a week previously; and he attempted to ascertain whether or not union had taken place, but desisted on account of complaints made by the plaintiff. He advised her to use her leg. He called again, December 27th, and then discovered that there was no union of the fragments. He then advised an operation for the purpose of fastening the ends of the bones together. The plaintiff was taken to a hospital in Sheboygan, where another surgeon performed an operation, ten weeks after which the plaintiff returned to her home, with the bone united perfectly, but her left ankle stiff. It was undisputed that prior to the operation there was never any exudate on the ends of the bones.

There was no evidence to show that the bones were not properly placed in apposition to each other, and there was no evidence to show that the weights were not properly attached in the usual and customary way. If an expert could not say that the treatment was improper, on what ground could the jury arrive at that conclusion. The fact being established that there was no union, it was assumed apparently that it must be due to some negligent treatment. The evidence did not sustain that view. The entire case here rested on the testimony of a physician to the effect that he would have treated the fracture in another way. Physicians are not compelled to choose at their peril between two accepted methods of treatment. Statements of experts that they would have treated the fracture in some other way are incompetent.

The trial court correctly instructed the jury that:

> A physician and surgeon is not an insurer or guarantor of a cure. If the treatment in this case was such as physicians or surgeons of ordinary knowledge and skill of the same school of medicine, and practising in the same vicinity, would have exercised under the same or similar circumstances, then the fact that a bad result followed from the treatment, if you find that that was the fact, is not in itself alone sufficient to charge the defendants or either of them with negligence.

The difficulty seemed to be that the trial court entirely ignored the undisputed fact that the failure of the fragments to unite was due to some cause with which the treatment administered by the defendants had nothing whatever to do; that is, the failure of nature to set up the healing process.

But there was one claim of negligence as to which there was sufficient evidence to sustain the finding of the jury, and that was that the defendant was negligent in not discovering the fact that the injury had not healed at the time of the removal of the extension apparatus, and in the defendant's further failure to call on the patient for seven or eight days thereafter. However, there was no evidence showing that this in any way contributed to or was a factor in producing the injury complained of.

At the time of the plaintiff's injury there was no roentgenographic apparatus at or near the place where she lived, and there was no suitable electrical current available. Neither did it appear from the testimony that, had a roentgenogram been taken during the treatment, it would have shown that no callus was being formed at the point of fracture. Nor was there cited any case holding that it is as a matter of law negligence for an attending physician and surgeon to fail to avail himself of the use of a roentgenographic apparatus in the case of fracture, and on the facts shown here this court cannot so hold, particularly as it was comparatively easy to determine whether or not the ends of the bones were in apposition. It is clear that under the facts in this case the failure to procure a roentgenogram during the course of treatment did not amount to negligence or unskilful treatment.

NO MALPRACTICE SHOWN IN TREATMENT OF FRACTURE AND OCCURRENCE OF INFECTION

(Lorenz vs. Booth (Wash.), 147 Pac. R. 31)

The Supreme Court of Washington affirms a judgment rendered for the defendant after a motion, at the close of the evidence introduced on behalf of the plaintiff, to withdraw the case from the jury and render judgment in favor of the defendant, on the ground that the evidence introduced in the plaintiff's behalf was insufficient to call for the submission of the case to the jury. The court says that the plaintiff had sustained a simple fracture of the tibia about 4 inches above the ankle. The defendant advised, and used, what was called the Lane method of treatment, consisting of opening the flesh and inserting and attaching to the broken portions of the bone a plate so as to hold them rigidly in apposition and alignment. The operation was performed at a hospital, where the plaintiff remained six days, after which he was taken home, when the defendant cut a hole in the cast so as to render the flesh wound accessible for treatment, and then it was first discovered that the injured parts had become seriously infected. Counsel for the plaintiff proceeded on the theory that the defendant was negligent in treating the broken bone by the adoption of the so-called Lane method, which required the opening of the flesh to the bone in order to attach the plate thereto, and that he was thereafter negligent in using unsterilized water and the vessel in which it was used to cleanse the injured parts when treating them. But the most that could be said of the testimony in support of the contention that the defendant was negligent in adopting the Lane method was that such method did not have, at that time, the unanimous approval of the medical profession. However, according to the only evidence presented in the plaintiff's behalf, that method did have the approval of at least a respectable minority of the medical profession, who recognized it as a proper method of treatment. This was enough to absolve the defendant from negligence so far as his mere use of that method was concerned, there being no showing that he exercised other than his best judgment in choosing that method. This court has heretofore recognized the rule that if there be more than one recognized method applicable to a particular case, the attending physician is not liable for an honest mistake of judgment in his selection of the method of treatment. Nor was there the slightest evidence but that every precaution known to medical science was exercised at the hospital looking to the prevention of infection. Yet the infection was discovered and had become serious at the end of that period. Up to that time there was nothing whatever pointing to negligence on the part of the defendant, unless the mere fact that infection had taken place was to be regarded as proof of his negligence; in other words, a bad result. But a mere "bad result" is not of itself ordinarily sufficient to render an attending physician liable for negligence; that is, it is not ordinarily of itself proof of such physician's negligence. Subsequent operations performed solely for the purpose of treating the infection were no evidence of improper treatment in the beginning. Neither was the defendant shown to have been negligent in the

use, after the infection was discovered, of water and basin claimed to have been improperly used for want of sterilization. The vessel was a common wash basin, which was cleansed with warm water and soap by the plaintiff's wife before use, and when the water was put into it the defendant would put into the water some kind of antiseptic tablets, the exact nature of which was not shown, and which method of sterilization was not shown to be insufficient or such as a prudent physician would not use. To have allowed this cause to be submitted to the jury would have been merely to permit it to speculate on the question of the defendant's negligence.

RELATION OF PHYSICIAN AND PATIENT—SKILL REQUIRED WITH REGARD TO LOCALITY

(*Viita vs. Dolan et al.* (*Minn.*), *155 N. W. R. 1077*)

The Supreme Court of Minnesota affirms a judgment against defendant Fleming for $2000 damages for alleged malpractice in the treatment of a fracture of the plaintiff's left leg between the knee and ankle. The court says that defendant Dolan died after this action was commenced. The defendants were partners as physicians and surgeons, and operated a hospital. They had an arrangement with the company in the employ of which the plaintiff was when injured by which the company deducted 75 cents a month from the pay of each employee, and turned this over to the defendants, who agreed for this compensation to care for and treat injured employees which the company should send to them. The plaintiff, after his injury, received a ticket from his employer, presented it to the defendants, and was taken into the hospital and treated. Defendant Dolan attended the plaintiff, who claimed that the failure to get a straight union was due to the omission of the defendants to apply an extension weight to the injured limb. Negligence was also claimed in respect to their failure to use a "fracture box" or to take a roentgenogram for diagnosis. Assuming that the relation of patient and physician existed, the court holds that the evidence was sufficient to justify the jury in finding that the physician failed to exercise toward the patient that degree of care and skill which the law requires. Nor were the damages awarded excessive. The defendants, however, contended that the relation of physician and patient did not exist, under the circumstances stated; but the court holds that it did, and that the defendants owed the plaintiff the duty to exercise ordinary care and skill in treating him. It was true, the court says, that the company, under the terms of the workmen's compensation act, was required to provide medical and surgical treatment to the injured employee during the first ninety days of his disability and to an amount not exceeding $100. But the court is unable to see how this changed the relationship between the injured employee and the physician or surgeon employed, or affected the duty of the latter to the former. Moreover, a settlement between the plaintiff and his employer under the workmen's compensation act, by which the employer was released from all claims on account of the injury to the plaintiff, did not operate as a settlement or release of any claim for malpractice which the plaintiff might have against the physician who treated him. The court thinks it is plainly correct that the locality in which the physician or surgeon practises must be considered in determining whether he has the requisite skill and learning, but the court does not think that he is bound to possess and exercise only that degree of skill and learning possessed by other practitioners in the same locality, if by that is meant the same village or city. If the same general locality is meant, as, for instance, the Northwest, or the state, no fault can be found with such a rule. But in these days the physician or surgeon in a village is not hampered by lack of opportunity for advancement. Frequent meetings of medical societies, articles in the medical journals, books by acknowledged authorities, and extensive experience in hospital work put the country doctor on more equal terms with his city brother. He would probably resent an imputation that he possessed less skill than the average physician or surgeon in the large cities, and this court is unwilling to hold that he is to be judged only by the qualifications that others in the same village or similar villages possess. It was not error to permit questions to the experts in regard to the propriety of taking roentgenograms. While this was not specifically alleged as a charge of negligence, the complaint contained a general allega-

tion of negligent treatment, and the court thinks this evidence was properly received, at least as against the general objection "incompetent, irrelevant, and immaterial."

SECOND INJURY FROM EXERCISING

(Kelley vs. Lembeck & Betz Eagle Brewing Co. (N. J.), 92 Atl. R. 282)

The Supreme Court of New Jersey affirms a judgment for $3750 in the plaintiff's favor for damages alleged to have been sustained by reason of a fracture of the patella caused by a defective cellar door owned by the defendant. The court says that the accident occurred January 28th, and that the plaintiff was taken to a hospital where he remained until February 20th, when he went home and put himself under the care of his own physician, who, according to the plaintiff's evidence, advised him after a time to do a little walking indoors. In May, while he was exercising under the instructions of his physician, he sustained a new fracture of the patella, presumably in the same place. Under the charge of the trial court he was allowed to recover for damages resulting from both fractures, if the jury should find that the proximate cause of both was the original negligence of the defendant. The defendant contended that the plaintiff was guilty of contributory negligence in undertaking to use the fractured bone before it had entirely healed, and requested a charge that the jury must not take into account any damages which were the proximate result of the second injury. This request was properly denied, because it required the court to take from the jury the questions whether the second injury was the proximate result of the original fall, and whether the plaintiff was guilty of contributory negligence in the respect just stated. This point, however, was for the jury in both aspects. There was evidence in the case that the plaintiff ought not to have left the hospital so soon, and should not have exercised, as he did. But the plaintiff swore that the hospital surgeon said that he could go, and that he waited another day before leaving. The plaintiff testified, also, that his own physician advised him to walk a little indoors. There was some testimony that the plaintiff was advised to consult a specialist, and did not do so; but it still remained a jury question whether he had used reasonable care in the selection of a physician and in following his instructions. If so, the defendant could not escape liability for a situation which, but for the original injury, never would have arisen.

METHOD OF TREATING COMPOUND COMMINUTED FRACTURE—EVIDENCE—AS TO NURSES

(Browning vs. Hoffman et al. (W. Va.), 103 S. E. R. 404)

The Supreme Court of Appeals of West Virginia says that the plaintiff, a boy about nine years old, suffered a compound comminuted fracture of the right leg, 2 or 3 inches above the ankle, and that this action was brought to recover damages for alleged negligence in the treatment of the injury in a private hospital conducted by the defendants as partners in business, one of whom, Dr. ——, dressed the wound, with the assistance of the family physician, on Monday evening. Dr. —— first thought that there should be an amputation, but, lacking the consent of the parents, decided to try to save the leg. After thorough cleansing and disinfection, taking out a loose sliver of bone, setting and wiring the bones, and closing the incision with sutures, the leg was put into a plaster cast, with cotton and gauze, and an opening or window left for drainage, inspection, and treatment. Dr. —— saw the boy on Tuesday morning and perhaps evening, and was then away until about 2 A. M. Thursday, in response to a call by the chairman of the Executive Committee of National Defense. Tuesday night the boy became delirious, and had a high temperature and a weak pulse. On the discovery of the unfavorable change, the head nurse, in addition to alteration of the treatment, endeavored to notify a young physician connected with the hospital, whose competence was not impeached, but she was unable to reach him before 10.30 A. M., when he visited the boy's room. The treatment adopted by the nurse was then continued, possibly with slight modification. The physician then tried to get into communication with members of the family, and made preparations to operate, but did not do so for want of consent. The father, a railroad man, was away until about 9 P. M., and was then unwilling to let the young physician operate, but was willing to let the family physician do it, while a rule of the hospital forbade operations there by surgeons not connected with

it. The result was that the boy was removed to Cumberland, Md., where his leg was taken off at the hip and his life barely saved. The result of the trial was a verdict for $5500 in favor of the plaintiff, from which $500 was remitted; and, besides, a new trial was granted.

The court holds that, if a surgeon adopts, in the treatment of a case, a method established and approved by physicians and surgeons, generally, in the community in which he performs the operation or gives the treatment, at the time thereof, and is not negligent or careless in its application, he is not liable for injuries caused by such treatment. If there are two or more approved methods of treatment of an injury of the kind committed to his care, he may adopt the one which, in his honest opinion, will be the more efficacious and appropriate under all of the circumstances, and, in such case, he is not liable for an injury resulting from an error in his judgment, if there be one. He is not bound at his peril to adopt the best method. The propriety of the use of a plaster-of-Paris cast in the treatment of a compound comminuted fracture of the leg having been established by uncontradicted evidence, in a case in which a surgeon is charged with malpractice in the treatment of the wound, it is error to give an instruction based on the hypothesis of negligence in the mere adoption and use of that method, even though an injury has followed, which might have resulted from use thereof in an improper manner. It is also error, in an action for malpractice by a physician or surgeon, to admit evidence of a method of treatment, antedating the treatment involved by a long period of time, and differing materially from the method adopted in the treatment and generally approved and used at the time thereof.

If, in the trial of such a case, incompetence of the nurses is relied on, and no evidence has been adduced for the purpose of proving it, except lack of graduation of the day and night nurses, the head nurse being a graduate, and there is no evidence of any omission of, or departure from, the instructions given them, or of any action or conduct on their part resulting in or causing the alleged injury, it is error to give an instruction founded on the assumption of evidence of their incompetence and negligence, or either of them. There was no evidence in this case of negligence on the part of any of the nurses. Not being physicians in charge of the patient, they had no authority to depart from the instructions given them by their employers. There was no proof that they did not obey their instructions or perform the duties assigned them, or that they were not properly instructed. Their failure to give correct information to members of the family, if any, or to remain at all times in the sick room, was not evidence of negligence contributing to or occasioning the result complained of.

COMPOUND COMMINUTED FRACTURE OF BONES OF LEG—EVIDENCE OF MALPRACTICE—USE OF FRACTURE OF BASKET

(Wojciechowski vs. Coryell (Mo.), 217 S. W. R. 638)

The St. Louis Court of Appeals, in affirming a judgment in the plaintiff's favor for $3000 damages for alleged malpractice, says that a sheet of steel fell on his right leg, causing a compound comminuted fracture of the bones and inflicting lacerations or wounds. He adduced evidence tending to show that it was negligence to place his leg in a wire basket, or fracture basket, after the setting of the bones, and to allow it to remain there for weeks, instead of putting it in a splint or cast of some character designed to hold the bones rigidly in position, unless it could be said, as a matter of law, that the course pursued by the defendant was justifiable because of the condition of the leg, or, at any rate, that because of such condition the defendant's failure to pursue a different course was the result of an error of judgment on his part of such character as would not entail liability under the law. As to the condition of the leg at that time the evidence in the plaintiff's behalf tended with much force to show that no infection, or at least none of any considerable extent, or of a serious or dangerous character, was present. This directly appeared from the testimony of the plaintiff as to the condition of his leg, and inferentially from his testimony, corroborated by that of another witness, to the effect that, after the setting of the leg, the bandage which the defendant placed about the leg and wire basket, which, it was said, completely covered the leg, no openings being left and no drain pipes inserted, was not

removed for three weeks or more, the leg receiving no treatment during that time. From the testimony of the plaintiff and said witness, coupled with the expert testimony adduced by the plaintiff, a jury could, with entire propriety, find that there was no infection or other condition present, such as to make it in any wise unsafe to use some one of the devices shown by the evidence to have been in common use, designed to keep the bones of the leg in proper alignment while they were uniting; and the testimony of the plaintiff's expert tended to show that some of these devices, designed so as to afford opportunity for treating the leg, might be used in these cases, though much infection might be present. The court is of the opinion that the evidence was such as to make the question of the defendant's negligence one for the jury. Nor, under the circumstances, does the court think that there was any merit in the contention that under any view of the evidence the defendant was guilty at the most of a mere error of judgment as to the proper treatment to be given the plaintiff's injured leg, and could not be held liable for a failure to give a different treatment. The court is of the opinion that the evidence, when viewed in the light most favorable to the plaintiff, tended to show neglect on the part of the defendant, and that, so viewing the evidence, if there was an error of judgment, it was, *prima facie*, of such character as to be inconsistent with the use of that degree of skill which it is the duty of every surgeon, under like circumstances, to bring to the treatment of such a case.

It was urged that error was committed in admitting testimony tending to show that the defendant failed to use an anesthetic, failed to take more than one roentgenogram, did not lance the wound, or insert drainage-tubes, did not elevate the leg, or apply ice-bags, did not call a consulting physician, and did not inform the plaintiff or his family of the seriousness of his condition, as testified to by the defendant. The point made was that the petition charged particular acts of negligence, and therefore evidence as to other specific acts was not admissible. But the court thinks that no reversible error intervened on this score. The testimony complained of was admissible as going to show the character of the treatment, alleged by the plaintiff to have been negligent and unskilful, or as tending to show the condition of the leg, this having an important bearing on the question as to the alleged negligent and unskilful treatment thereof.

Nor was it error to permit the jury to find that the defendant not only failed to use a splint, but "failed to apply any other method or device to cause said fractured bones to unite in normal and usual alignment." Under the evidence adduced the jury could properly find that in using the wire fracture basket the defendant did not use a method or device such as to cause the fractured bones to unite in normal and usual alignment.

THINGS A PHYSICIAN BY IMPLICATION GUARANTEES—NEGLIGENCE IN TREATING FRACTURE

(*Priestley vs. Stafford (Calif.) 158 Pac. R. 776*)

The District Court of Appeal, Second District of California, in affirming a judgment in favor of the plaintiff, a child, for damages (amount not stated) for alleged negligence in the treatment of a fracture of the radius and ulna of his right arm, says that while in actions of this character the injury and the fact that it resulted from the professional treatment administered must be established, such finding standing alone will not justify a recovery of damages by a plaintiff. On the part of a physician who undertakes the treatment of one suffering from disease or injury, there is no implied contract that such treatment will prove a success, or that ill and serious results may not follow as the direct result of such treatment. While "not a warrantor of cures," he nevertheless by implication guarantees that he possesses that reasonable degree of learning and skill possessed by others of his profession, and that he will in the treatment of his patient exercise reasonable and ordinary care and skill in the application of such knowledge to accomplish the purpose for which he is employed. And where he possesses such degree of learning and in applying it exercises ordinary care and skill, he is not liable for results that follow, In this case, since the contrary was not made to appear, it must be conceded that the defendant possessed the requisite professional skill and learning. But there was testimony of physicians which clearly tended to prove not only that the defendant was negligent by reason of the fact that he applied the splints and bandages in a manner which made no allowance for the

swelling of the arm accompanying such fractures, but also that he was negligent when, on being informed within an hour after leaving the child that he was suffering excruciating pain and complaining that the splints were too tight, he did not remove the splints himself or have them removed; and likewise negligent, when he visited the child the following morning and discovered the condition of the hand and arm, in not removing the splints in order to relieve the undue pressure which was then apparent. These facts, as well as others which the evidence clearly tended to establish, fully supported a finding of the court that the defendant, in treating the fractured arm of the plaintiff, did not exercise that degree of skill and care ordinarily exercised by the members of his profession practising in that and similar localities. That the child's hand and arm were badly crippled and deformed was conclusively shown; and since it must be conceded on the evidence that the condition of the hand and arm was due to undue pressure caused by the fact that the splints were adjusted in a manner which did not allow for the usual swelling accompanying such cases, the question as to whether or not such omission constituted negligence was one for expert testimony.

UNSUCCESSFUL TREATMENT OF FRACTURE AND FAILURE TO DISCOVER DISLOCATION

(*Houghton vs. Dickson* (*Calif.*), *155 Pac. R. 128*)

The District Court of Appeal of California, Second District, reverses a judgment for $3500 damages obtained by the plaintiff for alleged malpractice in the treatment of an injury to his right arm due to the kick of a horse, January 25th. It appeared that the ulna was fractured, and that, after receiving emergency treatment, the plaintiff, on the day following the injury, placed himself in the care of the defendant, who, after an examination with a fluoroscope, set the arm, using splints to retain the broken bones in place. On the following day, the defendant discovered that it would be necessary to wire the fractured ends of the bone, which he did at a hospital. The defendant dressed, bandaged, and otherwise treated the arm until March 29th, on which date the plaintiff consulted another physician. The latter found a dislocation at the elbow of the radius, that there had been no union of the ends of the fractured bone, that the wires used in securing the same had broken, and that pus had developed in the wound, all of which conditions, except the formation of pus in the wound, were indicated by a roentgenogram taken March 29th. The court holds that the evidence wholly failed to show any lack of care and skill on the part of the defendant in setting and treating the fractured bone, and failed to show when the dislocation occurred, or that a physician in the exercise of ordinary care and skill should, under the circumstances shown, have discovered the dislocation and treated it. Assuming that the radius was dislocated at the time when the defendant undertook the treatment of the fractured bone, or that it occurred thereafter during the treatment, such fact alone did not show that the defendant was lacking in ordinary care and skill in not discovering such condition. So far as it appeared, the defendant was called on to set the fractured bones. No intimation was given him of any injury to the elbow. Whether or not the defendant should, under the circumstances, in the exercise of ordinary and reasonable care and skill, have discovered such condition, assuming it to have existed, was a question for expert testimony, and none was offered. Conceding that the physician consulted March 29th had no difficulty then in discovering the dislocation, nevertheless that fact did not show a want of ordinary care and skill on the part of the defendant in failing to discover it, since the other physician, by reason of superior learning and advantages, might have been a man possessing far more than ordinary skill in his profession. The implied contract on the part of the defendant was, not only that he possessed that reasonable degree of learning and skill possessed by others of his profession, but that he would use reasonable and ordinary care and skill in the application of such knowledge to accomplish the purpose for which he was employed, and if he possessed such reasonable degree of learning, and in the treatment of the plaintiff's injury exercised ordinary care and skill in applying it, he was not liable for results that followed. In the absence of evidence to the contrary, the law will presume the exercise of a reasonable degree of care and skill.

DAMAGES FOR NEGLIGENT TREATMENT OF FRACTURE NECESSITATING AMPUTATION

(*McAlinden vs. St. Maries Hospital Association (Idaho), 156 Pac. R. 115*)

The Supreme Court of Idaho affirms a judgment in favor of the plaintiff, conditioned on his waiver to make it $8640, instead of $12,000. The court says that the plaintiff, while in the employ of a lumber company, one Thursday morning sustained a simple comminuted fracture of both bones of the right leg at a point about 2 inches above the ankle-joint. The lumber company had an arrangement with the defendant association whereby the latter, in consideration of a monthly fee paid by the employees into a hospital fund, treated them in cases of accident or illness. The plaintiff was taken first to a hospital of the defendant at another place, and on the following Monday afternoon to the one at St. Maries. The negligence complained of consisted in the placing on his leg, on said Thursday, of a circular plaster-of-Paris cast and a failure to remove or split it while he was at the first hospital, thereby causing a venous constriction of the limb, whereby it became infected with moist gangrene, which necessitated amputation near the juncture of the upper and middle third of the tibia and fibula. The defendant contended that the conditions which developed fully justified the use of the cast, and that the failure to remove or split the same, other than as was done, resulted in no injury to the plaintiff and was not the proximate cause of the amputation of the injured limb, but that this was due to dry gangrene caused by arterial injury. The court thinks the evidence was sufficient to support a verdict in favor of the plaintiff. If it were possible for men learned in the science of medicine and surgery to agree as to the exact result that will follow a given injury under certain treatment, or what is the proper treatment of a given injury, all doubt, touching the question of whether a physician or surgeon has properly treated the patient for the injury and just what constitutes diligent and skilful or negligent and unskilful treatment, might be removed. But where eminent physicians and surgeons emphatically disagree in their opinions, the most salutary method thus far provided for the administration of justice in cases of this kind is to submit these disputed questions of fact to a jury composed of twelve men of widely different walks of life and of radically different intellects, and permit them to weigh and average the whole evidence and arrive at a final unanimous conclusion. Whether the defendant's physician and surgeon exercised that degree of skill and learning possessed by the average member of the medical and surgical professions in good standing in the community, and used that reasonable care and diligence according to his best judgment in treating the plaintiff's injured limb that the average member of the profession would have used, were questions of fact exclusively for the jury to determine. This rule is not changed by reason of the fact that men learned in the science of medicine and surgery have given conflicting testimony touching the required and approved treatment of an injury. While it may be true in this case that the jury in reaching its verdict was not in a position to say beyond the possibility of a doubt that any one single fact in evidence or the absence of any one condition established conclusively the negligence of the defendant's physician and surgeon in placing the cast on the injured limb at the time and in the manner in which it was done, and in his failure to split the cast and thus permit free and uninterrupted venous circulation, yet if, from all the testimony and circumstances of the case, there was evidence sufficient to establish a *prima facie* case, the conclusion reached by the jury based on this evidence will not be disturbed on appeal. The court, however, thinks that $8640 should compensate the plaintiff for the pain and suffering, as well as the loss of the injured limb, so far as such loss could be properly compensated in dollars and cents. An examination of a number of authorities from other states showed that courts have invariably, for similar injuries, held verdicts in excess of the amount fixed by this court to be excessive.

DIAGNOSIS AND TREATMENT OF FRACTURES AS SPRAIN

(*Nickerson vs. Gerrish (Me.), 96 Atl. R. 235*)

The Supreme Judicial Court of Maine overrules a motion for a new trial, after a verdict for $5000 damages was returned in favor of the plaintiff, on condition that he remit all of the verdict in excess of $3000. The court says that the plaintiff, in walking in a railroad roundhouse, January 5th, stepped unawares into an ash pit about 3 or 4 feet deep, striking

his full weight on his right foot flat on the brick bottom of the pit, and thereby fractured both bones of his right leg, the fibula and tibia, about 3 inches above their lower ends. About eight hours afterward, he was attended by the defendant, who diagnosed his injuries as a sprain and administered treatment accordingly. Subsequently the defendant visited him six times, the last visit being January 14th or 15th. At that time the plaintiff was on crutches and suffering considerable pain; but, at his suggestion that he wished to get back to his office, the defendant advised that he might do so. The defendant did not see the leg again until February 4th, when the plaintiff called at his office, and it was "obvious to the eye" that there had been a fracture as the result of the accident. The defendant did not, however, inform the plaintiff of that fact, or then propose any treatment to reduce the fracture, but advised him to have the leg massaged and report in three days. On the evening of the same day, the plaintiff consulted another physician, and a roentgenogram of the leg was taken. The next day the defendant was paid for his services and discharged from the case. There was considerable testimony of physicians, on the one side and the other, as to the difficulty of diagnosing injuries to the lower leg or ankle, and as to the methods of examination for such injuries, and the relative utility of the different recognized tests which are used to detect fractures in the lower leg or ankle. But, while that testimony was not altogether in harmony, it disclosed a consensus of opinion that there are certain recognized methods of examination or tests to be used when the nature of such injuries is not obvious, but hidden and difficult of diagnosis. That the defendant was perfectly familiar with all the methods and tests recognized by the profession to be used in such examinations, and understood their relative usefulness, was conceded. He concluded that it was unnecessary in the plaintiff's case to have a roentgenogram taken of the leg, or to etherize the patient, and he relied on his manipulation of the injured parts and his examination for deformity or other possible indication of fracture, as affording him sufficient information on which to base his diagnosis. He made a mistake, however, and his diagnosis was wrong. But that fact alone was not sufficient to render him liable. Something else must be shown. And the issue before the jury in this case necessarily was whether that mistake was the result of a failure of the defendant to use painstaking care and diligence, and to exercise the best of his admitted learning, skill, and judgment in his examination and treatment of the plaintiff's injuries. That issue the jury found in the plaintiff's favor. A physician impliedly agrees with his patient that he possesses that reasonable degree of learning and skill in his profession which is ordinarily possessed by other physicians under like conditions, that he will use his best skill and judgment in diagnosing his patient's disease or ailment and in determining the best mode of treatment, and that he will exercise reasonable care and diligence in the treatment of the case.

ALLOWED TO SHOW ROENTGENOGRAM OF NORMAL PERSON AND TO QUOTE PHYSICIAN

(McGrath vs. Fash (Mass.), 139 N. E. R. 303)

The Supreme Judicial Court of Massachusetts, in overruling the defendant's exceptions in this action to recover damages for personal injuries, for which the plaintiff obtained a verdict, says that a physician who was a specialist in the use of the Roentgen ray was called as a witness by the plaintiff and testified concerning certain roentgenograms purported to be of the plaintiff's pelvic region, where the principal injury claimed by her existed. He said that the plates showed an abnormal condition of the pelvis, particularly with reference to the relation of the bones, some of which were alleged to have been fractured. He also produced another roentgenogram, which he testified showed the pelvic bones of a normal person, this plate being admitted in evidence subject to the defendant's exception.

It is settled that a roentgenogram showing the physical condition of a plaintiff in an action for personal injuries is admissible in evidence, and this court sees no valid reason why a plate of another person, properly verified by proof, which showed the pelvis in its normal condition, was not competent to assist the jury in understanding the nature and extent of the plaintiff's injury, in the same way that a skeleton is often exhibited in similar cases. Whether the plate was sufficiently verified was a preliminary question of fact to be decided by the trial judge, and was not subject to exception. As the plate in question

would have been of assistance to the jury in understanding the case, this court is of the opinion that it was admissible in the discretion of the trial court.

A physician called by the defendant testified that he had examined the plaintiff at the hospital. He described the injuries which he found and stated that there had been fractures of two bones of the pelvis, which were well set, and that the pelvis "was tipped a little bit." The plaintiff was called in rebuttal and testified that she remembered when she was examined by this physician. She was then asked as to what he said about her condition, and answered, "He told Dr. Robbins this was the worst accident case he handled in the last ten years." The defendant requested that the answer be stricken out; and the judge admitted it only so far as it tended to contradict any opinion or statement of the physician previously testified to by him. A majority of the supreme judicial court is of the opinion that the evidence as so limited was admissible in the discretion of the presiding judge. The jury might have found that it was more or less inconsistent with the testimony of the physician on his direct examination, in that he believed the plaintiff's injury was more serious than he had testified it to be. The statement made in the hospital had a tendency to contradict his testimony, and for this reason might be found to affect its weight. As limited by the presiding judge, the substantial rights of the defendant were not injuriously affected.

EVIDENCE OF NEGLIGENCE IN SETTING BROKEN ARM

(Knopp vs. Thornton (Ky.), 250 S. W. R. 853)

The Court of Appeals of Kentucky, in reversing a judgment entered on a verdict directed for the defendant, says that while the plaintiff was cranking an automobile, one of the bones of his forearm next to the wrist was broken and twisted around out of position, and the other bone of the forearm was dislocated. According to his evidence, he applied for treatment to the defendant, who pulled at the arm, laid it on a board on the plaintiff's knee, placed another board on top of the arm, bound it, and sent the plaintiff away, telling him that he need not come back until the end of six weeks, unless there was too much pain. Twice the plaintiff returned to have his arm examined, but the defendant gave him only casual attention. Later, the defendant removed the splint and told the plaintiff that the arm was all right, although it was a little crooked. However, roentgenograms were then made by other surgeons, who found that the ends of the broken bone were not together, but were in such a position that they would not unite, while the other bone was out of its socket. The gist of the defense was that the plaintiff had dislocated the bones after they had been set and bound by the defendant; but the plaintiff's evidence on this point directly and positively negatived that. He said that he did not jar or wrench his arm in any way; that he was very careful not to do so, following the defendant's instructions on that subject; that the bones in his arm were left exactly in the same position in which they were placed by the defendant. There was no evidence to the contrary. With the evidence in this condition, the trial court erred to the great prejudice of the plaintiff in directing a verdict for the defendant physician. The plaintiff had a right to have the case submitted to a jury.

The rule is that a physician holding himself out as skilled in the performance of surgical operations, who undertakes to perform an operation, must exercise such care as physicians and surgeons of that vicinity generally exercise in the performance of like duties; and if he fails to do so, he is liable in damages to a person injured by his negligence or carelessness. If the evidence of the plaintiff could be relied on, the defendant was not only negligent and unskilled, but directly responsible for much of the pain and suffering that the plaintiff endured, and for the failure of the bones of the arm to unite accurately.

NEGLIGENT TREATMENT OF FRACTURE

(Petefish vs. Morrison (Kan.), 205 Pac. R. 651)

The Supreme Court of Kansas, in affirming a judgment for damages in favor of the plaintiff, but without stating the amount of the judgment, says that the plaintiff's right leg was broken near the ankle, and the defendant was called to treat the injury. He

dressed the broken limb, braced it with a splint, and propped the foot straight forward with a pillow. The weight of the foot, however, caused it to turn outward, and in that position the fracture healed, so that thereafter as the plaintiff walked her right foot turned outward at an angle of nearly 90 degrees. An orthopedic surgeon testified that it is elementary in setting fractures that the limb must be placed in a normal position, immobilized, and held firmly by some method in its normal position until the bones have an opportunity to mend; that if the foot was rotated outward that was sufficient notice that the foot should be put back in a normal position and held there, independently of whether a roentgenogram was available or not. Many witnesses testified for the plaintiff that this precaution to keep the foot in position was not taken, and that it was permitted to lie over and outward to the right. The defendant's visits to his patient continued off and on for about three weeks before he discovered that her foot was everted, by which time the cartilaginous substance had so far formed that the foot could only have been straightened by more pain and suffering, while the record showed that the plaintiff had certainly borne enough of that, partly owing to the wrong position of her foot while the fracture was healing. For the defendant, there was evidence that the foot was correctly placed and the fracture properly treated; and it was argued for him that he undertook to render limited services only; that he told the plaintiff she should go to a hospital where a roentgenogram of her injury could be taken and where she would receive more attention; that her accident occurred during an epidemic of influenza; that he had so many patients he was going night and day, sleeping only three or four hours in the twenty-four, at the time; and that the eversion of the foot was caused by the plaintiff's own negligence. But the disputed facts were all disposed of by the jury's verdict; and, no error being found in the record of the trial, the judgment for the plaintiff was affirmed.

PATIENT'S IGNORANCE NO EXCUSE FOR REFUSAL TO FOLLOW ADVICE OR OBTAIN ROENTGENOGRAM

(*Carey vs. Mercer* (*Mass.*), *132 N. E. R. 353*)

The Supreme Judicial Court of Massachusetts, in sustaining exceptions to a judgment recovered by the plaintiff, says that the plaintiff's evidence tended to show that the defendant physician was negligent in failing to have a roentgenogram taken of the plaintiff's leg, which would have disclosed a fracture at the knee-joint. On the other hand, there was evidence that the defendant advised the plaintiff to have the roentgenogram taken, but that the plaintiff declined because of the expense involved. Furthermore, the defendant requested a ruling that, if the jury found that the roentgenogram was required to determine whether any bone of the plaintiff's leg was broken and that he had been so informed by the defendant and declined to have a roentgenogram taken, then the defendant was not responsible for not discovering the broken bone. That instruction should have been given.

The jury were instructed to the following effect:

"When a manual examination or an ordinary examination is made by a physician called to a case in which a suspicion of fracture may be present, it may be possible to determine the fracture without it; and if the examination discloses no fracture but there are symptoms present which to the ordinary and average physician would, in your opinion, require the further verification by a Roentgen-ray machine, and the physician fails to have a roentgenogram taken or at least to urge it on his patient, he would be negligent. Now you observe perhaps in that last statement a qualification. Ordinarily those of us who become ill or injured are quite willing to place ourselves entirely at the disposition of the physician we call and follow his advice carefully. Others possibly at times decline the physician's advice. It is no part the duty of a physicnan who has advised what, in his opinion, and what would, in your opinion, according to the standard of ordinary skill in the community, be necessary for the proper treatment of the case, to insist on it against objection on the part of the patient; but you would have to find that the patient fully understood and was informed of the reasonableness of the requirement and refused to follow the physician's advice, with a full knowledge of the consequences he was bringing on himself, in order to

justify the failure of a physician to take a roentgenogram, or to treat the patient in any other manner, solely because the patient refused to submit to the treatment or to follow the physician's advice."

There was error in that part of the instruction, "You would have to find that the patient fully understood and was informed of the reasonableness of the requirement and refused to follow the physician's advice, with a full knowledge of the consequences he was bringing on himself." That was not a correct statement of the law. If the roentgenogram was not taken because of the plaintiff's refusal, the defendant could not be charged with negligence in that respect. He was responsible to the plaintiff for failure to use the care and skill of an ordinary practitioner in the community where he practiced his profession. If a roentgenogram was essential in order to discover the fracture, and the physician, in the exercise of that degree of care required of him, advised that it be taken and the patient refused that advice, the physician could not be charged with negligence. The plaintiff could not hold the defendant responsible for the consequences of his own want of care, nor attribute to him damages resulting from his own neglect; and he could not complain if injury resulted from his refusal to follow the advice of the attending physician. A patient, when he places himself in the care of a physician, cannot decline to follow his advice nor adopt his suggestions because the patient does not possess full knowledge of the dangers involved in his own neglect, or in his failure to do what the physician recommends. The patient cannot charge the physician with negligence if the patient himself refuses to carry out the directions because ignorant of the consequences which might result from such failure. The patient may fail to understand fully the necessity of doing what the physician recommends, but he cannot attribute to the physician the damages which resulted from his own failure to have something done, when this was caused by his own conduct, even if he was ignorant of the consequences which would result from his refusal. If the rule were as quoted, it would place an unreasonable burden on the physician.

E. PRACTICAL CONCLUSIONS AND SUGGESTIONS

Unforeseen complications may arise in the simplest cases. There is no punishment for carelessness if all ends well. But if the results are less than expected, there is likelihood of an action for damages even where the utmost caution has been used. A surgeon cannot safely rely upon contributory negligence, for under such an issue the patient usually has the advantage in the matter of furnishing evidence.

Many cases coming to trial show a mistake in diagnosis. Every possible means should be employed to avoid error in diagnosis. A Roentgen ray should always be demanded and secured no matter what the conditions may be. In case of doubt a consultant should be used in every fracture case. The most approved methods should be used. The best apparatus should be employed. Examination of the fracture and patient should be sufficiently frequent to make absolutely sure that the exact progress of the case is recognized, recorded, and understood.

Instructions to the patient or responsible relative or friend and nurse should be definite and absolute obedience to them should be insisted on. When dealing with a critical situation a friendly witness or two may well be present unostentatiously, but present. While ordinary care is all that is required, there must be extraordinary vigilance to make positive that this required degree of care is always reached. Complete records of fracture cases should be kept. Risks in care and treatment should not be assumed

unwisely. Great optimism as to the result of a fracture should be unexpressed.

Malpractice suits originate from various causes. Among those recognized causes may be mentioned the following[1]:

Carelessness in making examination, diagnosis, and records of cases. In nearly all instances where suit is brought or threatened some physician has encouraged such suit by a careless expression of disapproval of the treatment given a patient. Many cases are brought or threatened as counterclaim to avoid payment for medical services.

About one-half the suits are believed to be caused by careless or malicious comments of other physicians.

More frequently cases are due to gossip or thoughtless remarks by physicians. A dissatisfied patient, a jealous doctor, and a hungry lawyer are the usual factors.

[1] Amer. Med. Assoc. Bulletin, Bureau of Legal Medicine and Legislation, November, 1925.

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